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FIG. 1.—Mont Pelé from Morne des Cadets, distant 9 km. S. 15° E. from the new cone. The base of the cloud below the spine marks nearly the level of the former summit of the mountain.
Photographed March 31, 1903, for the American Museum, by E. O. Hovey.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XXVI.—*The New Cone of Mont Pelé and the Gorge of the Rivière Blanche, Martinique;** by EDMUND OTIS HOVEY. (With Plates XI–XIV.)

THE world-wide interest which was aroused in the eruptions of Mont Pelé on the island of Martinique and La Soufrière on the island of St. Vincent, which devastated large portions of those islands in May, 1902, and succeeding months, has led to a large amount of study being devoted to these volcanoes by geological commissions and independent geologists from the United States, England, France† and Germany. The purpose of the present article is to record some of the changes which have occurred in and on Mont Pelé since the observations made directly after the eruptions began were published.

Undoubtedly the most striking change which has taken place in either volcano, after the first devastation had been accomplished, is the complete alteration of the sky-line of

* In May, 1902, the author was sent by the American Museum of Natural History to study the eruptions on Martinique and St. Vincent (see Bull. Am. Mus. Nat. Hist., xvi, pp. 333–372, October, 1902, this Journal, IV, xiv, pp. 319–358, November, 1902, and the Nat. Geogr. Mag., xiii, pp. 444–459, December, 1902). In February, 1903, the same institution sent the author on a second expedition to the region to note what changes had taken place in the volcanoes since the previous visit, make additional observations under the more favorable conditions incident to the dry season, and extend his studies to the other recent volcanoes of the Caribbean chain.

† In the fall of 1902 the French government established two observing stations on Martinique, one of which (Morne des Cadets) was provided with seismographs and all other needful apparatus, and systematic and continuous observations have been maintained ever since. The commission has consisted of Professors A. Lacroix, J. Giraud and Rollet de l'Isle with the assistance of Captain L. Perney at Morne des Cadets on the west side, and Adjutant L. Guinoiseau at Assier on the east side of the island. Some of the results obtained by the commission have been utilized in preparing the historical part of this communication.

Mont Pelé. Morne Lacroix, the ancient summit of the mountain, has lost most of its former prominence above the rim of the crater, but within the old caldera a cone has risen which overtops the surrounding walls and terminates in a spine rising hundreds of feet above the main mass of the new cone.

Prior to the beginning of the present series of eruptions,* the mountain was characterized by a great crater about a half a mile across and one thousand to two thousand feet deep below the level of the crater-rim. On the southwest side the crater-rim was breached to the base by a great gash which was continued into the gorge of the Rivière Blanche. Nevis and Montserrat to-day stand as close analogues, on a smaller scale, of Mont Pelé before the eruptions. Within the great crater of Mont Pelé lay the small crater-lake known as L'Étang Sec, and from three or more openings around this lake began the uprush of ejecta which has proved of such moment in the history of the island. A cone or series of cones began forming at once, as is shown by the accounts† of several persons who visited the crater late in April and found cones of "cinders" built up about two vents west of l'Étang Sec and one to the eastward thereof.

The photographs and sketches, taken and made by the author and other observers on May 21, 1902, from the U. S. tug "Potomac," show the existence of a comparatively small cone in the crater at the head of the gorge of the Blanche. This cone was variously estimated at from 200 to 300 feet, certainly not more than 500 feet, in height, but nothing was

* Although the eruptions frequently are spoken of as having begun in May, 1902, the increasing activity of the volcano had been noted long before, and in March the sulphur gases pouring out of the volcano were causing inconvenience to the inhabitants of the coast region between Prêcheur and Ste. Philomene. The St. Pierre daily, *Les Colonies*, in its issue for April 25, 1902, says:

"Depuis quelques semaines, les habitants du quartier du Prêcheur sont constamment incommodés par une forte et désagréable odeur de soufre qui se dégage du cratère du volcan éteint. L'odeur est si forte, parfois, que les chevaux, passant sur le grand chemin du littoral, hésitent.

"Depuis cette nuit, une fumée blanche très épaisse se dègage du cratère. Elle attire de tous côtés des groups des curieux.

"Dans les hauteurs de la Pointe-Lamarre le sol est couvert d'une cendre épaisse.

"De temps en temps la fumée s'arrête pour être vomie ensuite par masses énormes. C'est sans doute alors que sont lancées les matières solides que l'on aperçoit, parait il, avec la lunette de la chambre de commerce. . . . . ."

The first outthrow of cinders seems to have occurred April 23, 1902. In conversation with the author, Mr. Fernand Clerc, a prominent citizen of Martinique, stated that he (Mr. Clerc) had visited the summit of the mountain on May 8, 1901, and had observed that a new fumarole had come into vigorous action in the southeastern part of the crater, while the two well-known vents in the western part of the crater, west of the lake known as l'Étang Sec, were more active than before.

† See *Les Colonies* for May 7, 1902, as quoted in the *Century* Magazine for August, 1902.

observed then to indicate that it was anything other than an ordinary fragmental cone built up by the pericentric deposition of ejecta from the vent or vents. This was after the first-class eruptions of May 8, 19 and 20.

The new cone must have grown with great rapidity, for Professor Heilprin's account and Mr. Varian's sketches* describing and illustrating what was seen on an ascent made May 31, indicate that it must then have attained at least the altitude of the eastern crater rim, or about 3,950 feet above the sea. The surface of l'Étang Sec according to common report was about 700 meters (2,296 feet) above tide. If this determination can be relied upon,† the new cone had an altitude of about 1,455 feet above its base on May 31, 1902. Mr. Varian's sketches and Professor Heilprin's description indicate the existence of great walls or dikes of solid rock in the new cone and Mr. George Kennan's account‡ corroborates this evidence. None of these observers reported the existence of a spine or tooth projecting above the cone.

On June 20, 1902, Mr. George Carroll Curtis and the author got occasional glimpses of the new cone during two or three hours spent on the summit of the volcano. The vertical walls reported by Heilprin, Varian and Kennan were not to be seen —perhaps they had been partly destroyed by the heavy eruption of June 6. The sides of the cone were steep and showed great masses of rock, but in the constantly shifting, momentary views obtained through the steam June 20, these were held to be enormous loose masses in a fragmental cone. The top of the cone was very jagged and the points seemed to surround a shallow crater which was the most active vent.§ No point projected far above its fellows. On June 29, from the sea, Lacroix saw a point emerge from the clouds for a moment.‖ Its altitude was determined by Ensign Deville on board the "Jouffroy" at 1353 meters (4,439 feet), which was so nearly the altitude given for old Morne Lacroix, the former summit of the mountain, that the point was not recognized as being new.

Photographs taken early in July, 1902, show a prominent elevation rising like a shark's fin above the southwestern portion of the new cone. The reports of the gendarmes of Morne

* McClure's Magazine, August, 1902.

† Le Prieur, Peyraud and Rufz however in their official report, "Eruption du Volcan de la Montagne Pelé (1851)," p. 17, published by Ruelle and Arnand, government printers, Fort de France, 1852 (?), give the altitude of the lake at 921 meters (3,021 feet) by aneroid measurement, but their determination does not seem to be accepted.

‡ The Tragedy of Pelée, p. 157. The Outlook Co., 1902.

§ See Bul. A. M. N. H., xvi, pl. 44, fig. 2 and this Journal, IV, xiv, p. 356, fig. 14, for an illustration of the cone as it was on June 20, 1902.

‖ Journal Officiel de la Martinique, October 24, 1902.

Rouge first mention seeing the new cone above the crater rim on August 11 (Lacroix), but no note is made of the existence of a terminal tooth. Heilprin states* that on August 24 he saw horns projecting obliquely from the southwestern part of the new cone, but he does not mention any spine projecting vertically from the top, nor does one of his photographs† indicate the existence of any such feature. He considered the cone to be built up of débris.‡ From the occurrence of the great eruption of August 30, Mont Pelé remained covered almost continuously with clouds and steam until early in October.

On October 10, Lacroix saw from the observatory at Assier the top of the new cone projecting like a cap above the crater rim, and having approximately the same altitude as the remains of Morne Lacroix close by. During the immediately succeeding days the cone grew rapidly, stretching in a north-south direction, and attaining an altitude of about 90 meters (295 feet) above the rim of the crater. Examination through a telescope convinced Lacroix that this top was composed of "solid" rock, not débris, and led him§ to advance the idea that Pelé now was to be classed as a *cumulo-volcano*, a theory which his subsequent observations and those of his colleague Giraud, and of Sapper,‖ Heilprin¶ and the author have fully confirmed.

October 15, 1902, the same observer** stood on the edge of the great crater, and noted that the new dentate ridge rose then but 50 meters (164 feet) above his view-point, and that it had one tooth notably higher than others. Since this date the prominent spine or tooth has grown wonderfully and varied greatly in size and form from time to time. Occasionally there has been a loss of several or even many meters from the top, but the loss has always been recovered within a short time. On November 8, the 100-meter high tooth with its almost vertical walls, the northeastern side of which looked

* Mont Pelée and the Tragedy of Martinique, p. 181. J. B. Lippincott Co., 1903.

† Ibid., plate facing p. 288.

‡ Ibid., p. 281 and elsewhere.

§ Comptes Rendus, October 27, 1902. Author's separate p. 2. *Idem*, December 1, 1902. Author's separate p. 5.

‖ Centralblatt für Min., Geol. u. Pal., 1903, p. 348.

¶ Communicated in a letter to the author under date of July 10, 1903.

** Comptes Rendus, December 1, 1902. Author's separate, p. 4. In this account Lacroix speaks of the tooth as being but 100 meters from the eastern edge of the great crater (Morne Lacroix). When one stands on the top of Morne Lacroix, the great spine or tooth seems overpoweringly near at hand; the true relations, however, can be seen best from the south or the north, whence the base of the rock spine is judged by the present writer to be not less than 150 meters from Morne Lacroix. Sapper (Centralblatt für Min., etc., pp. 350, 351) has mistaken the position of Morne Lacroix, making it part of the old Somma ring of the volcano, whereas, what there is left of it stands directly on the great crater rim and forms an integral part thereof.

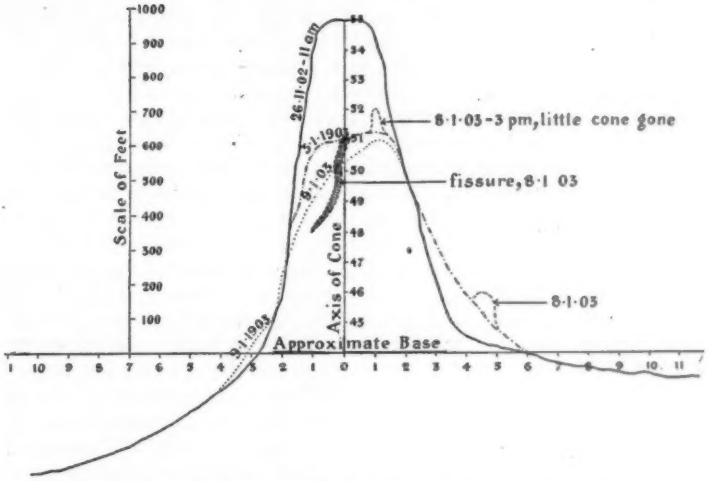

FIG. 2.—The cone of Mont Pelé, as seen from Morne Fortuné, St. Lucia.
First phase, from November 26, 1902, to January 9, 1903.
After sketch by Major W. M. Hodder, R.E.

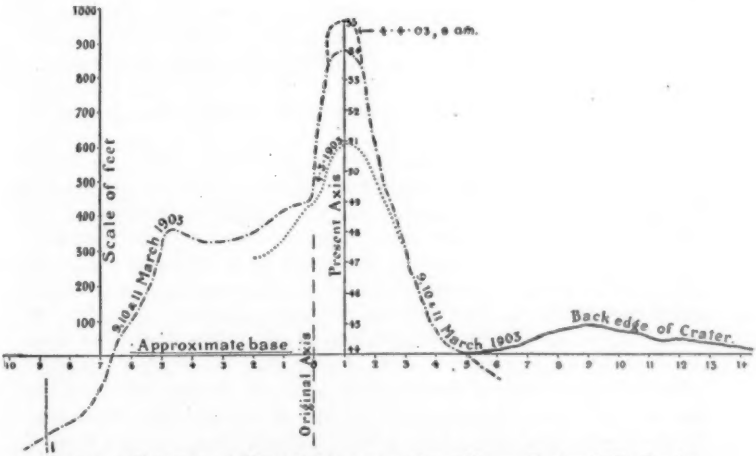

FIG. 3.—The cone of Mont Pelé, as seen from Morne Fortuné, St. Lucia.
Second phase, from March 4 to April 4, 1903.
After sketch made by Major W. M. Hodder, R.E.

"polished," was the absorbing feature in the view of the new cone from the crater rim beside Morne Lacroix;* this tooth was only beginning to be noticeable three weeks before. At the end of March, 1903, the French Commission† determined the apex of the spine to be 1,568 meters (5,143 feet) above the sea, or 338 meters (1,109 feet) higher than the remains of Morne Lacroix, but in the meantime there had been a period when the cone had reached nearly this maximum and had fallen again. After each considerable explosion the cone is seen to have changed more or less. Portions have fallen off and the altitude has usually diminished. One of the heaviest eruptions which have occurred since August, 1902, took place at 6:12 P. M., March 26, 1903. The next morning Captain Perney, at Morne des Cadets, found that the apex of the spine was 25 meters (82 feet) lower than before the outburst. In April the official bulletins of the commission record a further loss of six or seven meters. In the early part of May, there was a recovery of a portion of the lost altitude, but during the night of the 30th, fifty meters of height disappeared from the spine. The feeble activity of June, however, restored twenty-five meters of the loss.

The profiles reproduced herewith as figures 2 and 3 show the appearance of Mont Pelé as seen from Morne Fortuné, the barracks of the British regiment stationed at Castries, St. Lucia. The observations were made by Major W. M. Hodder of the Royal Engineer Corps at favorable times from November, 1902, to April, 1903, and supplement so well the history of the cone as given above that they are published here, with Major Hodder's permission. Morne Fortuné, at St. Lucia, is fifty nautical miles from the cone of Mont Pelé, but the clear atmosphere which prevails occasionally enables the taking of satisfactory observations.

Quoting substantially from Major Hodder's letter of April 18, 1903, regarding these sections: "Morne Fortuné [the point from which the observations were made] is 835 feet above sea level. We first saw the cone [spine] clearly on 26 November, 1902 [see fig. 2], when I fancy it had attained its maximum. We saw it again just before Christmas, but I could not measure it. It had become obviously lower, and wider at base. I got excellent observations during the first nine days in January, during which time the cone was visibly altering. After that we did not see it again until 4 March, 1903. [See fig. 3.] We had heard that during February the cone had been almost destroyed. You will observe that in the second

*A. Lacroix in Journal Officiel de la Martinique, November 22 (?), 1902. Quoted from a reprint.

†Lacroix, La Depêche Coloniale (Paris), April 30, 1903, p. 98.

phase the axis of the cone is about 100 feet east of where it was in November, also the ridge of rock to the left appears new. The actual cone is also quite different in shape. The first looked like a huge lighthouse, the second like a church steeple. You will observe how rapidly it grew upwards from 4 March to 9 March. My observations were excellent then, so that there can be no doubt about the growth.

"Piton Carbet was my test for altitude, so that refraction, etc., could not produce much proportional effect. Of course since my theodolite reads only to minutes I can count on accuracy at such a distance only within about 20 feet one way or the other, or a maximum error of about 40 feet, but as I took a series of observations I think the error must be much less. On 4 April the cone had reached the same altitude as on 26 November, 1902 [5,032 feet above the sea]." *

These profiles show very clearly the course of events in the history of the new cone during a little more than four months. Morne Fortuné is about S. 12° E. of Mont Pelé, or practically in line with Morne des Cadets, so that figures 2 and 3 give essentially the same outline as that obtained from the French observatory. The altitude for the cone, 5,032 feet, obtained by Major Hodder on November 26 indicates an increase of not less than 735 feet in 18 days, or about 41 feet per day on an average. Probably the rate was much more rapid than this at times, for the growth according to the bulletins of the French Commission was not uniform, and there were days when the cone had lost some of the height shown on the preceding day. Judging from the determination of the more favorably located French observers, Major Hodder's values are somewhat low (see page 272).

Between November 26, 1902, and January 3, 1903, according to figure 2, the spine lost about 340 feet of altitude, but became wider at base. About January 8 began the series of ruptures which split off great slabs from the southwestern side of the spine and changed its shape from that of a "lighthouse" to that of a "church steeple." The shifting of the axis to the eastward seems to have been due, in part at least, to this loss of material from the west side of the spine and in part to the elevation to the eastern side of the spine in a more nearly vertical line from the base.

From January 9 to March 3 no observations could be made from St. Lucia on account of the clouds hanging about the cone. On March 3, according to figure 3, the apex of the

* Major Hodder's letter gives the details of the triangulation by which he determined this altitude. His observations gave the altitude of Piton du Carbet as 3,936 feet, 24 feet less than the height given on the chart. In calculating the height of Mont Pelé, however, he assumed the chart to be correct.

cone was about the same elevation as on January 9; during the next six or eight days it had risen 275 feet, and in another month (April 4, 1903) it had gained another 132 feet, or more.

The author's observations of the mountain and its surroundings in 1903 extended from February 17 to March 1 inclusive, and from March 19 to April 3 inclusive, together with a perfect view of the cone from a sloop becalmed off St. Lucia on March 15. The new cone itself was seen at sufficiently close quarters for productive study on February 17, 19, 20 and 21 from St. Pierre and elsewhere on the southwest side and as far up the mountain as Morne St. Martin at an altitude of 500 meters (1,640 feet), directly in front of the V-shaped gash in the crater walls; on March 21, 25 and 26 from the crater rim, when fully three-quarters of the circuit of the crater was made; on March 28 from the Grand Réduit on the Morne Rouge—St. Pierre road; on March 29 from Morne des Cadets and from St. Pierre; on March 30 from the heights north of the Prêcheur river and then all along the coast back to Carbet; on March 31 and April 2 from the observatory at Morne des Cadets, and from the steamer "Rubis" off St. Pierre on the later date; and on April 3 from the steamer "Yare" en route to Dominica.*

The rim of the crater is irregular in height, rising from 1,070 meters (3,510 feet) beside the head of the Rivière Blanche gorge† to 1,210 meters (3,969 feet) beside the basin of the Lac des Palmistes, and it culminates in the remains of the rock-mass of Morne Lacroix, which the author determined at 1230 meters (4,034 feet) as the average of two readings of his aneroid barometer taken five hours apart on March 21, 1903.‡ North

* The author also spent twenty-four hours on or near the summit plateau (i. e., the Lac des Palmistes basin) February 27 and 28, but the dense fog and rain which caused his guide to lose the way, prevented the making of any observations of the cone. Almost the only note made during that unwilling night's sojourn on the mountain was a negative one—no sound of detonation or grumbling came through the ground to the author's ear during the twelve hours of darkness when he was lying in a gully for shelter from the fierce gale. It does not follow, however, that no explosions took place during this period; the tremendous wind would have prevented almost any sound from traversing the atmosphere contrary to it.

† In June, 1902, Mr. Curtis and the author assumed the crater (see Bull. A. M. N. H., xvi, p. 352; this Journal, IV, xiv, p. 337) as beginning at a rock mass jutting from the south side of the gorge at 3,350 feet (1,021 meters). March 26, 1903, this rock-mass was not observed, and the slight turn in the rim marking the beginning of the crater was at the altitude given here (1,070 meters). The rock-mass seen June 24 and 26, 1902, may have been partly undermined and removed by the intervening blasts and the remainder so covered with mud as not to be noticeable from fifty yards above.

‡ June 20, 1902, Mr. Curtis and the author made Morne Lacroix to be 4,200 feet (1,280 meters) above the sea. (Bull. A. M. N. H., xvi, p. 352. This Journal, IV, xiv, p. 337.) Much of the mass of what was seen then has disappeared and the height lowered 166 feet.

FIG. 4.—Mont Pelé. The new spine from beside the head of the gorge of the Rivière Blanche, looking about N. 30° E. The apex is about 500 meters (1,640 feet) above the point of observation.

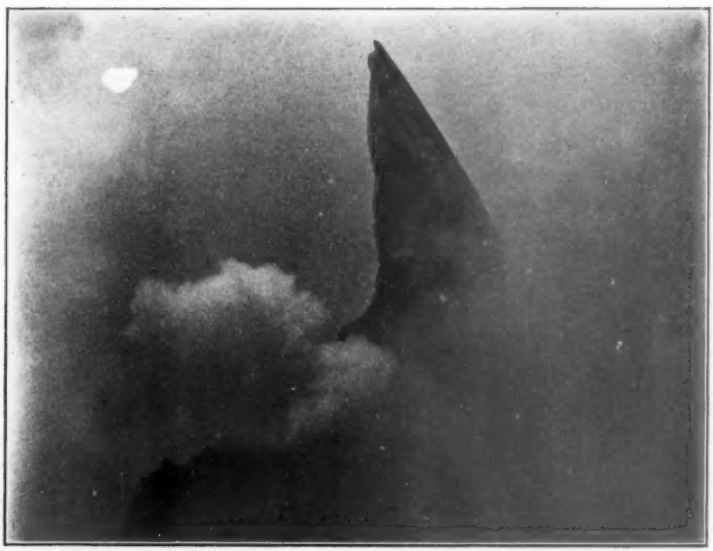

FIG. 5.—Mont Pelé. The top of the new spine from the crater-rim, looking about N. 30° W.

Photographs taken March 26, 1903, for the American Museum, by E. O. Hovey.

FIG. 6.—Mont Pelé. The new spine from nearly the same point of view as the preceding. Photographed March 15, 1903, by the Comte de Lameth. The fissures and vertical grooves are well shown. The spine seems to have been about 25 meters (82 feet) lower than on March 25.

FIG. 7.—Mont Pelé. The new spine from the basin of the Lac des Palmistes, looking about S. 60° W. The apex is about 358 meters (1,174 feet) above the rim directly in front. The remains of Morne Lacroix are visible at the right on edge of the crater. Photographed March 25, 1903, for the American Museum, by E. O. Hovey.

FIG. 8.—Southwestern part of Mont Pelé, showing the ash-filled gorge of the Rivière Blanche, February 17, 1903.

FIG. 9.—Mont Pelé. A portion of the ash-filled gorge of the Rivière Blanche, February 20, 1903.

From American Museum Journal for July, 1903. Photos. by E. O. Hovey.

of Morne Lacroix the altitude of the rim decreases gradually till the middle point of the northern rim is reached, where the author got a reading of 1,130 meters (3,706 feet) beside a precipice which prevented further progress westward. The rim here dropped 10 meters, perhaps, but soon rose again, and the western edge of the crater is essentially horizontal at an elevation (judging from the heights above Prêcheur) of about 1,150 meters (3,772 feet) till the remains of Petit Bonhomme are reached. This rock-mass, the only one besides Morne Lacroix on the edge of the crater, overhangs the northern side of the gorge of the Blanche (i. e., the great gash). It seems to have lost some of its altitude and mass since June, 1902; then its altitude was judged by Curtis and the author to be about 4,000 feet (1,220 meters), while in March, 1903, it could hardly have exceeded 1,180 meters (3,870 feet).

The crater is wider than it was in June, 1902, the increase being toward the east, south and southwest. On the east and south the tuff walls are almost if not quite vertical. Numerous landslides have occurred here, and in March, 1903, it was necessary to exercise great caution in traversing the rim on account of the cracked condition of the agglomerate.* The V-shaped gash in the southwestern rim is wider, or rather the southern side of it has been cut away, but the débris from the new cone nearly fills it.

The new cone with the great spine is not central within the old crater. The most important of the openings concerned in the present series of eruptions were on the west side of the old crater-lake, L'Étang Sec, so that the new cone has been built up northwest of the center of the old crater. The spine rises from the northeastern quarter of the new cone. This has resulted in the complete filling of the northwestern quarter of the crater, making the slope of the new cone on the west and northwest sides continuous or nearly continuous with the exterior of the old crater-rim. On the northern, eastern and southern sides, between the new cone and the crater-rim, there is a shallow spiral valley which debouches into the gorge of the Rivière Blanche on the southwest. The deepest part of this valley seems to be beneath the ruins of Morne Lacroix, and is estimated to be about two hundred feet deep below the old crater-rim. It seemed much deeper (500 to 800 feet) during last June. On the southwest the new cone slopes continuously into the débris filling the gorge of the Blanche.

The new cone is a composite affair made up of fragmental ejecta from the vents, lava which has welled up or been pushed

* The edge shown in Bull. A. M. N. H., xvi, p. 44. fig. 1, and this Journal, IV, xiv, p. 356, fig. 13, has been pushed back an indeterminable number of feet and the inner slope is practically vertical instead of having an angle of 65° from the horizontal.

up from below, and masses which have fallen or been blown off from the latter. The spine or tooth consists of "solid" rock which seems to have been pushed up bodily into its present position, and to be maintained there, somewhat like the stopper in a bottle, by friction against the sides of the neck and by the expansive forces underneath. The shape of the spine, with its sides forming angles of 75°, 87° and even 90° with the horizontal, is a strong argument against the theory that it has been formed by ejected blocks or bombs which were sufficiently pasty to stick together on falling, and in favor of the "stopper" theory. Furthermore, the northeast side of the spine presents a fairly smooth, vertically grooved surface, as if it had been slickensided by friction against the side of the conduit during its ascent (see figs. 5, 6 and 7, Pl. XII, XIII). The great and sudden changes in the altitude of the spine with reference to the rest of the cone point in the same direction.

Great ribs or dikes of lava extend to the sides of the new cone from the base of the spine on the northeast, southeast, south and west. Those of the southern and southeastern portions of the cone appear in fig. 4, Pl. XII. The lofty tooth or spine is rifted and fissured in every direction, and portions of it are constantly falling from its sides. Some of the vertical fissures are very prominent on the east side and evidently connect with fluid lava beneath, for they have been observed* to become luminous at night from below upward, and the light has died out gradually from above downward. The author was not fortunate enough to witness this phenomenon, which substantiates the cumulo-volcano theory so well; he only saw the cone luminous at the base of the spine on the southwest side, which is the source from which have originated most of the recent heavy dust-flows and minor eruptions.

The northeast side of the spine is strikingly different in appearance from the southwest side thereof. The former shows a nearly smooth surface which is almost polished in its effect. In the light of the rising sun the spine looks like an enormous white monument rising above the mountain. The true color of the northeast side of the spine, however, is more a reddish brown with a whitish incrustation over a part of it. The southwest side of the spine constantly shows fresh surfaces on account of the portions falling off, and this side is gray or reddish gray in color.

No one can say yet exactly what the nature of the spine is, but the probabilities are that it is largely pumiceous in texture, judging from its being so rifted, from the readiness with which the masses break off from it and especially from the abundance of pumice in the new material filling the gorge of

* Lacroix, Comptes Rendus, Dec. 1, 1902. Author's separate p. 5.

the Rivière Blanche. The surface presented by the northeast side is probably solid and glassy through different conditions of cooling. The bombs, which lie in profusion over the basin of the Lac des Palmistes and other parts of the crater rim, are of all kinds from wholly pumiceous with a thin, densely vitreous crust to those which are mostly lithoidal in texture. The author found one true bomb on the edge of this basin which was fresh pumice in the interior with the usual fresh, densely vitreous crust about an inch in thickness, but a part of the exterior portion of the mass was formed by a lump of oxidized agglomerate. Evidently this mass had been in contact with the walls of the conduit through the old tuff beds of the volcano. Usually one can readily distinguish between bombs which are true bread-crust bombs in the sense that they are portions of the fresh magma which have been blown into the air, where they consolidated, and those which consist of fragments of ancient lava beds which have been broken off and recently reheated to a molten or plastic condition and then ejected. The latter often show characteristic surfaces of conchoidal fracture which are not observed on the former, and they are more lithoidal in texture than the former. Angular fragments of lithoidal lava, one-fourth to one-half inch (1 cm.) across, coat parts of the crater rim near the Lac des Palmistes basin, apparently blown there from the new cone.

There is now no central opening or pit-like depression in the top of the new cone corresponding to the general idea of a crater. The incomplete glimpses of the active cone obtained in June, 1902, seemed to the author* to indicate the existence at that time of a true crater in its top, as has been mentioned on page 271. The growth of the spine has destroyed this crater, if it ever had any long-continued existence. Steam issues with vigor from all parts of the cone, but especially from the top and from the southeastern portion, but not from the spine. Minor explosions occur from the southwestern side at an elevation of apparently about four thousand feet (1,220 meters) above the sea, and from the northwestern side at a somewhat greater elevation. Heavy outbursts have taken place on December 16, 1902, January 25, 1903, and March 26, 1903, with less important ones on other dates, from the southwest side of the cone near the base of the spine or from 4,400 to 4,500 feet (about 1,375 meters) above the sea. There is no one definite conduit through the cone or spine itself, to the exclusion of others.

Next to the new cone and spine, the most striking change in Pelé, to one who was familiar with the appearance of the

* Bull. A. M. N. H., xvi, p. 355, and pl. 44, fig. 2. This Journal, IV, xiv, p. 340 and fig. 14.

mountain before the eruptions began, is the filling of the gorge of the Rivière Blanche with calcined rocks and dust and ashes (lapilli) which have been poured out of the crater by the numerous eruptions (see Pl. XIV). This was the gorge extending seaward from the great gash in the southwest side of the old crater which determined the direction of the explosive volcanic blasts which swept over St. Pierre on May 8 and succeeding days. Now the lower portion of the gorge has been entirely obliterated and the adjoining plateau elevated, while the upper and deeper portion near the crater has been almost filled by the ejecta. The line of this gorge is still the favorite direction of discharge of the volcano, and the great bowlders scattered thickly over the surface attest the violence of the explosions (see fig. 9, Pl. XIV).

The material has been carried into the gorge by the dry dust-flows which have swept down from the crater and from the new cone with great velocity and terrible force. These dust-flows consist of steam saturated with dust to such an extent that the mixture acts like a highly mobile fluid. Great masses of rock are transported by it as easily as corks are carried along by water. As the flows proceed on their way they drop their load of stones and liberate vast volumes of steam which carry into the atmosphere the finest dust from the flow. The clouds of dust always are incandescent when they leave the cone, but they lose their high temperature during the latter part of their course to the sea.* The beds of ash may retain heat enough for several months to furnish occasional dust-flows. This has been observed in the re-excavated gorge of the Wallibou River, St. Vincent. On March 6, 1903, a cauliflower column of dust was seen to rise from one of the ash beds left in an angle of the gorge, and the next day the author found that a dry dust-flow had taken place, covering an acre or two of the bottom of the gorge with a hot dust- and pebble-flow from one or two feet to eight or ten feet in thickness.

Unquestionably a portion of the filling of the gorge of the Blanche has been done by flows of mud. The mud-flow which overwhelmed the Usine Guérin seems to have been caused by the waters of the Étang Sec breaking through a temporary dam formed by new ash from the western vents within the crater, but succeeding mud-flows have been caused by the rain-soaked dust and ash on the slopes of the great crater and the remainder of the drainage-basin of the Blanche descending in

*Lacroix (Comptes Rendus, 26 Jan., 1903, author's separate p. 2) determined by means of metal wires put in the path of the dust clouds about 6 km. (3¾ mi.) from the center that the temperature at that locality was less than 230° C. for the heavy cloud of December 16, 1902, while his thermometer showed the dust to retain a temperature of 125° C. two days after the eruption.

terrible avalanches. It is not difficult, however, to distinguish the mud-flows from the dust-flows, at least when both are fresh.

The mud-flows when dry are hard and compact, and are black or nearly so; the dust-flows are very light gray in color and have a calcined appearance, and are so soft and loose that one sinks in them nearly to the knees. Water, however, will cement together the surface of a dust-flow, forming a crust over it. Mud-flows, especially where their motion is comparatively slow, show a surface wrinkled transversely to the direction of the flow, while dust-flows do not present such a phenomenon.

Enormous masses of rock, some of them forty feet across, lie scattered about along the middle altitudes of the Séche-Blanche plateau, some of which were thrown there probably by the eruption of August 30, 1902, while others were ejected by the earlier outbursts. These lie out of the line of and considerably higher than the path of the dust-flows down the Blanche, hence the suggestion that they were hurled through the air during a part at least of the journey to their resting places. Some of the blocks were broken into many fragments through striking on other rocks, while others landed in ash and were not even cracked. On the summit and eastern side of the mountain, especially, "bread-crust bombs" are more numerous than they were in June.

In spite of the fresh lava forming the spine, the dikes in the new cone, and the numberless bombs, no *stream* of molten lava has issued from Pelé during the present series of eruptions. This phenomenon is probably due to the great excess of water-vapor (steam) connected with the eruptions, as compared with the amount of liquid lava rising in the conduit or series of conduits. The excess of water vapor combined with the viscidity of the lava has caused the outbursts to be violently explosive without permitting the quiet exudation of liquid rock in sufficient quantities to form streams.

The author's subsequent studies of the Grande Soufrière of Guadeloupe and the peak of Saba on the same expedition lead him to the conclusion that they have passed through the phases through which Mont Pelé is now passing, and that they belong to the same class of volcanoes. This is especially clear in the case of the Grande Soufrière, the cone of which rises above an old crater-rim which it has buried in the same way that Mont Pelé is now striving to bury its surrounding crater-walls; and great dikes intersect and spines surmount the cone. Bombs closely similar in appearance to those of Mont Pelé occur on the Grand Soufrière of Guadeloupe and on Saba.

American Museum of Natural History,
July 15, 1903.

Art. XXVII.—*The Colors of Allotropic Silver;* by J. C. Blake.

[Contributions from the Kent Chemical Laboratory of Yale University—CXIX.]

A great deal has been written concerning the allotropy of silver, perhaps the most remarkable phenomena described being the beautiful color effects obtained by Carey Lea.* No satisfactory explanation of such effects has ever been published, however. I have repeated most of the work described in the literature relating to "allotropic" silver, "colloidal" silver, and, to some extent, the so-called "sub-salts" of silver, and have arrived at the conclusion that all of the color effects observed may be explained by assuming the existence of three or possibly four allotropic forms of silver. Before describing these forms it will be necessary to point out specifically that each of them has a characteristic color in reflected light, and another, very nearly complementary color in transmitted light. In the case of mirrors transparent to certain wave-lengths of light, the colors of the reflected and transmitted light are commingled when such mirrors are viewed in ordinary light, to mutual obliteration. The confusion of colors resulting from the commingling of the various allotropic forms of silver among themselves, as well as the blending of colors due to the intermixture of allotropic silver and foreign colored substances, especially when such intermixtures are present in solution together, must be constantly borne in mind.

These four assumed allotropic forms of silver, together with their most pronounced characteristics and convenient modes of preparation, are as follows:

Form of silver, named after the color most readily observed.	Color in reflected light.	Color in transmitted light.
"White silver"	Nearly white	Nearly opaque, even in the thinnest films
"Blue silver"	Golden yellow	Blue
"Red silver"	Indigo-blue	Red
"Yellow silver"	Indigo-blue	Yellow

The transmitted colors are easily observable. They are the colors seen when the substances are in pseudo-solution—permanent suspension or colloidal solution,—and in mass, provided no mirror surface has been formed. The colors in reflected light, on the other hand, are observable only when a mirror surface has been formed, either by deposition on glass, by

* This Journal, xxxvii, 476, and many articles closely following. Phil. Mag., xxxi, 238, 320; xxxii, 337.

spreading on glass or other material, by undisturbed sedimentation from water, by burnishing, or by crystallization. In proportion as the mirror surface becomes more and more imperfect, the reflected light of "white silver" changes toward gray, the reflected light of "blue silver" changes to copper-colored, the substance finally appearing black. The light reflected by "yellow silver" has been observed only in the case of mirrors on glass, backed by bone-black. Indeed, "yellow silver" has been obtained satisfactorily in no other form. All four forms of silver have been obtained suspended in water, but suspensions of "blue silver" and "red silver" alone are permanent—the so-called colloidal solutions.

"White silver" is formed by treating "blue silver" and "red silver" with strong acids in considerable amount, and, consequently, whenever silver is thrown out by reduction in strongly acid solution. Roughly speaking, the greater the concentration of the acid present the more nearly white the silver will be. It is ordinarily gray, as noted by Lea in the transformation of his allotropic forms of silver to the "ordinary" form by treatment with acids. Silver nitrate reduced by ferrous sulphate in solutions sufficiently dilute gives a colloidal solution of "blue silver." In stronger solutions a gray, opaque precipitate is formed ("white silver"). If, however, a little sulphuric acid be first added to the ferrous sulphate solution, the product is plainly crystalline silver consisting of perfect and distorted microscopic octahedra; and the greater the dilution and the stronger the acid, within the limits tested, the more distinctly crystalline the silver will be and the more its color will approach to white. Such crystals are usually intermixed with grape-like clusters which, if crystalline, show no evidence of it in their external form.

"Blue silver" may readily be obtained in a great variety of ways, as indicated in Table I. It is, in fact, formed whenever silver is reduced in neutral or alkaline solution in the presence of small amounts of electrolytes and without the presence of too much organic matter. When electrolytes in sufficient amount are added to colloidal solutions of "blue silver" aggregation and subsequent sedimentation take place, the coagulum appearing blue or black when settled in mass according to its compactness and volume, the addition of salts and alkalis in sufficiently large amount tending to produce the black effect.

When such a blue or black precipitate of "blue silver" is spread upon glass while moist, the particles arrange themselves in mirror surfaces. If the preparation is made and handled in the dark, these mirrors reflect a very deep and rich golden color, transmitting blue light. No preparation was found which gave these mirrors in better form than those obtained

by following Lea's directions for the preparation of his "gold silver"; that is by the action of Rochelle salt and ferrous sulphate on a solution of silver nitrate. Drained and dried quietly in masses, these preparations give Lea's golden lumps.

Heat converts this blue silver to "white silver." Pressure does the same, and with great ease in the case of mirrors on glass. Exposure to light gradually brings about the same effect, the golden reflection slowly paling. If such mirrors of "blue silver" are originally prepared in the daylight, the surface reflection at first is pale yellow, which likewise fades into white by lapse of time. This partially converted yellow reflecting silver is Lea's "intermediate" form, scarcely sensitive to pressure. Its pale yellow color may reasonably be attributed to the dilution of the golden yellow surface-reflection of "blue silver" by the white light reflected by intermingled "white silver" formed by the exposure to daylight.

Mirrors of "red silver" and of "yellow silver" on glass may be conveniently prepared by the action of silver nitrate upon an ammoniacal solution of tannic acid, and mirrors of "red silver" may likewise be readily obtained by spreading on glass portions of the red-brown precipitate formed in the mixture. The mirrors of "yellow silver" thus formed tend to change into "red silver" spontaneously, and both, when gently heated, are transformed into "blue silver." These mirrors of both forms of silver are slowly soluble in water, but mirrors of "red silver" are stable for some weeks under atmospheric conditions, ultimately becoming dull gray and lusterless.

Colloidal solutions of "red silver" of approximate purity can be readily obtained by reducing a solution of silver nitrate with ferrous citrate (ferrous sulphate and sodium citrate) in the presence of a little free alkali, according to Lea's method of obtaining his "A" form of silver. The mother liquor should be withdrawn by suction through a porous cell, as recommended by Schneider, and the red precipitate suspended in water. If no free alkali is added the solution will be blue (experiment (19) of the table), a trace of free alkali in excess rendering most collodial solutions more stable. On adding an electrolyte in sufficient amount to such a red solution, the silver is changed to "blue silver" and usually settles out. If the yellowish brown mother liquor has not been removed, the addition of an electrolyte will cause the solution to look green instead of blue, owing to the commingling of colors. To the intermixture of yellow sulphur is due the blue-green effect observed in experiments (39) and (48) of the table. "Red silver" may be looked for whenever silver is thrown out by reduction in the absence of electrolytes, or in the presence of electrolytes in small amount, accompanied by considerable amounts of organic

matter or typical colloids. This effect of typical colloids in rendering colloidal solutions of the metals more stable, discovered by Faraday, has been investigated at length by Zsigmondy* and others.

Mirrors formed by spreading on glass portions of a precipitate of "red silver" containing electrolytes, like that obtained by the action of ferrous citrate, transmit red light and reflect indigo-blue light only while moist. At the moment of drying, the substance suddenly changes over to "blue silver"—a change which undoubtedly served to prevent Lea from recognizing clearly the distinction between "red silver" and "blue silver," especially as he was accustomed to observe the "surface" and the "body" colors of these substances, instead of differentiating the colors of the reflected and transmitted light. When mirrors which show the color change are viewed in ordinary light after drying, the reflected (golden) and transmitted (blue) lights are commingled and the mirrors have a beautiful bright fluorescent green appearance. This effect was seen by Lea, who determined that the blue and the yellow colors were oppositely polarized.

Another variety of green effect, noted by Gutbier† in the action of hydrazine hydrate on a solution of silver nitrate, is still more deceptive. The green in this case is due to an intermixture of "blue silver" with "yellow silver" formed simultaneously. In order to see this it is only necessary to act with hydrazine hydrate on a solution of silver nitrate at considerable dilution. No action takes place for some minutes; then an orange-yellow color appears in the liquid and a yellow mirror forms on the sides of the containing vessel. Such yellow mirrors may even form in the more concentrated green solutions. In solutions still more concentrated pure blue effects may be readily obtained. The same sequence of colors was observed less clearly in other cases.

The detailed observations are collected in the following table. It is to be understood that the solutions used, both of the silver compounds and of the reducing mixtures, were in no case very strong, those marked "concentrated" containing about five or ten grams of the material per liter, those marked "dilute" containing from a tenth to a hundredth part as much. Care was taken to avoid a local excess of any electrolytic reagents employed, and the reducing mixture was always finally added in excess of the silver compound. Except for the purpose of avoiding known precipitates, the order in which the

* Zeitschr. anal. Chem. xl, 697. Schulz and Zsigmondy, Hofmeister's Beiträge, iii, 137. Lettermorer and Meyer, Jour. prakt. Chem. lvi, 248.

† Zeitschr. anorg. Chem. xxxi, 448; xxxvii, 347.

TABLE I.

A. Water Solution of Silver Nitrate.

Reagents.	Opaque precipitate, color in reflected light.	Solutions, color in transmitted light.			
		Blue.	Red, dilute.	Red, concentrated.	Yellow.
1. Formalin	If large excess, gray	Hot or moderate excess.	On standing		
2. Formalin + NH_4OH		Mirror			If little ammonia; mirror
3. Formalin + NaOH		+			
4. Hydrazine hydrate		+			If dilute, mirror
5. Hydrazine hydrate + ether		+			"
6. Hydrazine hydrate + alcohol		+			"
7. Hydroxylamine		+			
8. Hydroxylamine sulphate + NH_4OH	Hydroxylamin sulph. in excess, gray	+			If little ammonia; mirror
9. Phenylhydrazine		+			
10. Ether + $FeSO_4$ (trace)		Add ether first, mirror			
11. Chloroform + NH_4OH		+			
12. Chloroform + $FeSO_4$		Soon changes to AgCl			
13. Carbon bisulphide + $FeSO_4$		+			
14. Hypophosphorus acid		+	Unstable		Unstable
15. Phosphorus acid		+	+		
16. Phosphorus trichloride + NH_4OH		+			
17. Phosphorus in ether					+
18. Phosphorus in ether + NH_4OH		+			
19. Sodium citrate + $FeSO_4$		+			
20. Rochelle salt + $FeSO_4$		+		If little $FeSO_4$ w. prec., turns red	
21. Rochelle salt + NaOH		+	Turbid, stable		
22. Sodium citrate + NaOH + $FeSO_4$				Stable if little $FeSO_4$	
23. Rochelle salt + NaOH + $FeSO_4$				"	
24. Tannic acid + NH_4OH or NaOH				Mirror, stable	Mirror, unstable
25. Tannic acid + NaOH + $FeSO_4$				Solution, stable, mirror, unstable	
26. Sulphur dioxide			White prec., turns pink		

TABLE I (continued).

B. Ammoniacal Solution of Silver Nitrate.

Reagents.	Opaque precipitate, color in reflected light.	Solutions, color in transmitted light.			
		Blue.	Red, dilute.	Red, concentrated.	Yellow.
27. Formalin	If large excess, gray	+			
28. Phenylhydrazine		+			
29. Chloroform		+			
30. Chloroform + NaOH		+			
31. Methyl alcohol + NaOH		+			
32. Ethyl alcohol + NaOH		+			
33. Amyl alcohol		+			
34. Amyl alcohol + NaOH		+			
35. Hypophosphorus acid		+			
36. Phosphorus acid		+			
37. Phosphorus trichloride in NH_4OH		+			
38. Sulphur dioxide			Slowly, faint pink		
39. Acid sodium sulphite		Blue-green, unstable, contains sulphur		Unstable	Unstable

C. Ammoniacal Solution of Silver Oxide.

40. Formalin	If large excess, yellowish-gray	+	Stable		
41. Formalin poured into silver solution; dilute	Yellowish gray changes to purple solution		Purple, stable		
42. Hydrazine hydrate		+	Stable		
43. Hydroxylamine sulphate		+	Stable		
44. Hypophosphorus acid		+	Stable		

D. Water Suspension of Silver Oxide, filtered after treatment.

45. Hydrazine hydrate		+			
46. Hydroxylamine			Turbid, stable		

E. Water Solution of Silver Nitrate, slightly acid, with Sulphuric or Nitric Acid.

47. Phenylhydrazine		+			
48. Acid sodium sulphite, solid or in concentrated solution		Blue-green, contains sulphur, turns black		Coagulated by shaking	Coagulated by shaking

reagents are added is usually immaterial, although if a non-electrolyte which alone does not cause reduction of the silver compound is to be added, it is best to mix it with the silver solution before adding the final reducer in order to take advantage of the power which non-electrolytes possess of inhibitating the action of electrolytes toward colloidal solutions, as already pointed out. The resulting colloidal solutions were generally clear in ordinary light, but all gave the Tyndall effect when the light was concentrated with a lens. Except when otherwise stated the colors refer to transmitted light. A + sign indicates that the phenomenon takes place without special characteristics or conditions.

In the light of the foregoing discussion most of these results will be readily understood. It will be noticed that the gray effects ("white silver") were obtained only in acid solutions. In solutions sufficiently acid such effects are always obtained. The tinge of yellow noted in experiments (40) and (41) was doubtless due to the golden reflection of intermixed "blue silver," formed while the solution was still alkaline, as in experiment (2). The blue solutions obtained in experiments (3) and (10) were especially stable. In most cases the blue color was preceded by a red, brown, green, or purple color. It was found impossible to prepare red silver solutions which were stable except in the presence of organic matter or typical inorganic colloids, as stannic acid. "Yellow silver" was never obtained in stable solution. Except for the fact that glass is colored yellow by silver and not red, this "yellow silver" might be regarded as a variety of "red silver." The other forms of silver—"white," "blue," "red"—seem sufficiently distinct to be regarded as allotropic forms until their exact properties can be investigated. So far as that work has progressed it fully bears out the idea that silver does exist in allotropic forms.* Grimm worked with silver mirrors which transmitted blue-gray light, and found that the increase in electrical conductivity induced in them by lapse of time, by heat, light, burnishing, and other agencies, all indicated a gradual change from "molecular" to "normal" silver, corresponding, in the terminology here used, to the change from "blue silver" to "white silver."

The kind advice and helpful assistance of Prof. F. A. Gooch, who suggested this subject for investigation, is gratefully acknowledged.

* Grimm, Drude's Ann. [4] v, 448.

Art. XXVIII.—*Notes on the Development of the Biserial Arm in Certain Crinoids* ;* by Amadeus W. Grabau.

In 1898, while working in Professor R. T. Jackson's laboratory at Harvard, I noticed that in a perfect arm of *Encrinus liliiformis* the apical portion was uniserial. This feature had never been stated to be the case in any text-books or works on crinoids that were available, and figures of this species of Encrinus always show the condition of imperfect specimens, with the apices of the arms broken away and the biserial arrangement unchanged to the end. It is, of course, well recognized that crinoids the adults of which have biserial arms are uniserial when young, the change from uniserial to biserial beginning at the tip of the arm and passing gradually proximal-wards. But that, after the animal has reached the biserial condition, the new plates added at the top begin uniserially and only later on become biserial, has never been explicitly stated, so far as I am aware, though it may have been recognized. Wachsmuth and Springer, indeed, after speaking of the arms of the young Platycrinus as strictly uniserial, go on to say: "In somewhat older specimens, the plates at the tips gradually interlock, and new ones still forming at the distal end *are strictly biserial.*† With advancing maturity the interlocking gradually extends to the proximal ends, until finally in the adult Platycrinus *the whole arm becomes biserial,*† except perhaps as to a few plates near the calyx, which permanently retain their larval condition."‡ This, as shown beyond, is not the case in any perfect specimen of Platycrinus which I have examined, not even in *P. huntsvillæ*, which is used as an illustration of their statement by Wachsmuth and Springer.

The facts here discussed have apparently been recognized by Bather, for he writes: "The change from uniserial to biserial . . . . . begins in both ontogeny and phylogeny at the growing tip of the arm, and proceeds gradually proximal-wards."§

* This paper was originally read before the Boston Society of Natural History, Nov. 7, 1900. It was again read at the Albany meeting of the Geological Society of America, January, 1901. Its publication has been deferred in the hope of finding more illustrative material, but this has been only partially realized. A summary was published by Jackson in his memoir on localized stages in development. I am under great obligation to Professor Jackson for loan of specimens from his laboratory, to Mr. Schuchert for loan of material from the National Museum, and to Mr. Edwin Kirk, student in Columbia University, for access to his collection of crinoids.

† Italics are mine.

‡ Wachsmuth and Springer, North American Crinoidea Camerata, vol. 1, p. 79.

§ Bather, F. A., The Echinoderma, Part III, of Lankaster's Treatise on Zoology, p. 116, 1900.

The arguments which this paper attempts to support may be briefly stated as follows: 1. So far as observations have been made on perfect material, new arm plates introduced at the tip of the growing arm are uniserial. 2. The apical plates, at least in the less specialized biserial species, are rectangular, and change with further growth to wedge-shaped and later to biseriality. 3. This is not primarily an old age character, since this condition is found in the apical arm plates of young crinoids. (See fig. 4.)

The following theses are suggested, but not proved. They may be borne in mind in further study. *a.* In specialized or accelerated genera the newly added plate *may* be wedge-shaped instead of rectangular. *b.* In highly specialized genera the newly added plates *may* be biserial. *c.* In old age individuals the last added plates *may* never pass beyond uniseriality, the animal losing the power to further modify the plates. *d.* In extremely phylogerontic types the biserial condition of the plates *may* be dropped out, and a uniserial type thus derived from a line which at its acme was supplied with biserial arms.

The Case of Encrinus liliiformis.

In this species the uniserial condition of the terminal plates was first noted in a perfect specimen belonging to Professor R. T. Jackson of Harvard. Other perfect specimens showing the uniserial terminal plates were studied in the collection of the Boston Society of Natural History and in that of the University of Rochester. The first brachial of *Encrinus liliiformis* is nearly rectangular, while the second is axillary. Above this the 1st plate of the divided arm (No. 1 in fig. 1) is roughly an oblique parallelogram, followed by a somewhat wedging plate, the thinner edges of the wedges being directed towards each other in the two arms of a series. This much may be considered as incident upon the division of the arm. Above this, however, are three plates of the primitive rectangular type, after which (the 6th plate of the separate arm) the plates begin to wedge out, quickly becoming shorter (the 7th plate only rarely extends all the way across the arm), and by the 9th or 10th plate normal biserial conditions are established. It is not until the 16th or 17th plate, however, that the characteristic tubercles appear on the inner side of the plates. At first these tubercles are faint, but they quickly become of normal strength.

In figure 1, the right member of each of two arm groups is represented. In *a*, normal biserial conditions continue up to the 79th plate, after which the plates become more wedging. Not, however, until the 85th plate is reached are uniserial con-

ditions found. This plate is completely wedge-shaped or cuneate and extends entirely across from side to side. This cuneate condition continues to the 87th plate, after which the wedge becomes more and more truncated, and the upper and lower sides more and more parallel, until in the 96th plate the rectangular outline of the primitive plate is all but retained. Thus there are at least twelve uniserial plates at the tip of this

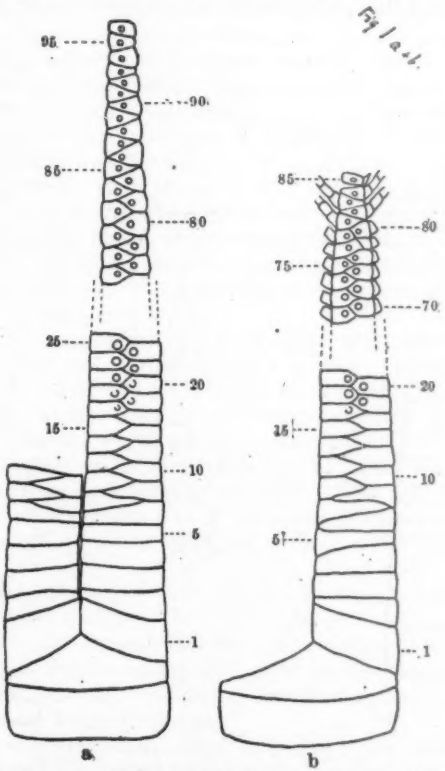

FIG. 1, *a–b*. Encrinus liliiformis. Diagram of arms showing uniserial apical plates. (Harv. Univ. Pal. Lab. Coll.)

arm. The faint development of a tubercle on the 96th plate suggests that this is not the terminal one, and that the arm is therefore not quite perfect. (Compare fig. 2.)

In an adjoining arm of the same individual (fig. 1b) biserial conditions continue to about the 80th plate, but there is a slight inequality of development in plates 77 and 78, the former of which is developed at the expense of the latter. Plate 81 is

the only perfect wedge-shaped plate, the succeeding ones approaching a rectangular outline, which is nearly, if not quite, reached in plate 85 by a rather abrupt transition. It will be seen that this arm is retarded with reference to the adjoining one (fig. 1*a*). Thus in arm *b* plate 81 is still wedge-shaped, while in arm *a* the corresponding plate has already become biserial. Again, plate 85 in arm *b* is rectangular, or nearly so, while in arm *a* this plate has already become perfectly cuneate.

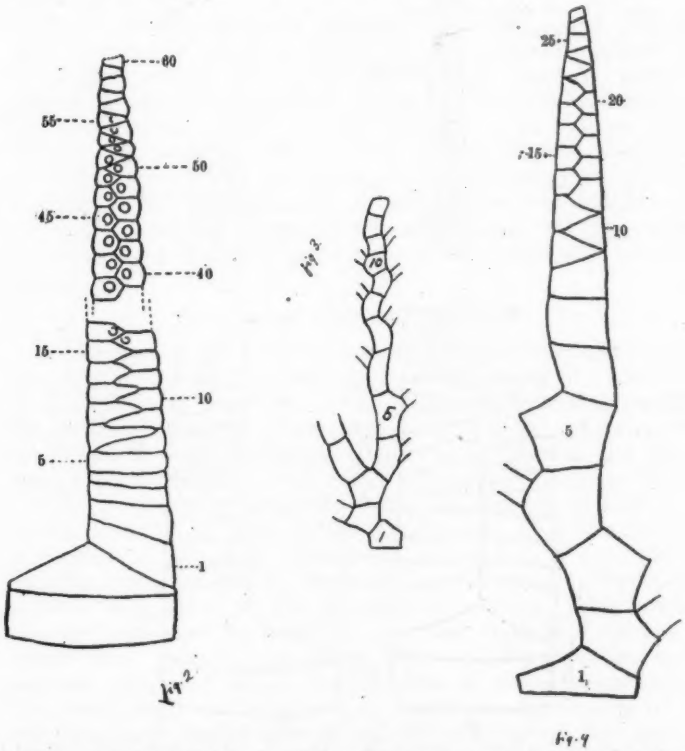

Fig. 2. Fig. 3. Fig. 4.

FIG. 2. Encrinus liliiformis. Diagram of arm showing uniserial apical plates. (Coll. Bost. Soc. Nat. Hist.)

FIG. 3. Platycrinus huntsvillae. Diagram of arm of young individual, showing uniserial character of plates. Length of arm, 9mm. (Kirk Coll.)

FIG. 4. Platycrinus huntsvillae. Diagram of arm of youthful individual, showing uniserial apical plates. (Kirk Coll.)

Since we cannot postulate a difference in age between the two arms of the same crinoid, we must consider that one is retarded in development with reference to the other.

An arm of a somewhat younger individual in the collection of the Boston Society of Natural History is illustrated in fig. 2. Here, normal biserial conditions continue only to plate 49, after which the plates are wedged out, extending all the way across in plate 53. Plate 60, the last one preserved, approaches closely to primitive rectangular outline. Here there are at least ten uniserial plates, the upper five of which are without median tubercles. Compared with fig. 1*a* this arm is much less developed, having nearly thirty-five fewer biserial plates. This is readily accounted for if we consider specimen fig. 2 as a younger individual, which appears to be indeed the case from the size of the two specimens. A number of specimens of this species in the collection of Rochester University show uniserial conditions at the apex.

In an immature individual, in the left arm of a pair, the 76th arm plate is wedge-shaped and extends entirely across the arm. Rectangular plates are not preserved. In the adjoining right arm, which is less accelerated, the 73d and 74th plates are wedge-shaped, extending entirely across the arm, while the 75th plate is a truncated wedge.

In an older specimen (left arm) the 89th plate is wedge-shaped but does not extend entirely across. The 90th, however, does extend all the way across the arm and is the lowest uniserial plate at the apex of the arm. The 92d plate is still truncated, while the 94th is broadly truncated.

In the youngest individual yet seen (left arm) the 7th is the first biserial plate, as in adults generally. The 43d plate, however, is still wedge-shaped and uniserial. The 44th plate is slightly truncate, the 45th more so, while the terminal plate is rectangular.

A somewhat abnormal individual (left arm) has five normal rectangular plates above the two oblique ones at the base. The 8th plate still extends across but is wedge-like. The 9th hardly extends across, being still more wedge-shaped. From the 67th plate upwards the plates are wedge-shaped and uniserial, extending entirely across.

In the various species of *Encrinus liliiformis* examined we have thus found the lowest apical plate in which uniseriality is retained to be the following:

Specimen No.	1st arm.	2d arm.
4. (Univ. of Rochester)	89	
1. (Harvard Univ.)	85	81
3. (Univ. of Rochester)	76	73
6. (" ")	67	
2. (Bost. Soc. Nat. Hist.)	52	
5. (Univ. of Rochester)	43	

In this series, specimen 4 is the oldest, all the plates up to the 89th having matured or nearly so, while specimen 5 is the youngest, only forty-two plates having matured.

Quenstedt (Petrefactenkunde Deutschlands, iv, p. 461, pl. 106) figures what he considers the apex of a perfect arm. His figure (164) shows biseriality to the end, but with the plates more wedge-shaped. He figures a very young individual of *Encrinus liliiformis* (fig. 178, p. 406) in which the arms are

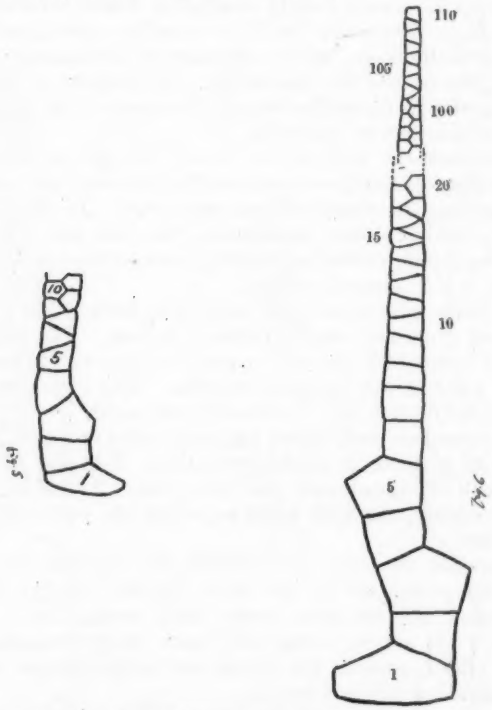

FIG. 5. Platycrinus huntsvillae. Diagram of basal plates of adult arm. (Kirk Coll.)

FIG. 6. Platycrinus hemisphericus. Diagram of arm showing terminal uniserial plates. (Harv. Univ. Pal. Lab. Coll.)

uniserial throughout, the plates of the middle arm, however, showing a wedge character. The terminal ones are perfectly quadrangular. The same thing is true, according to Beyrich, of the young of *Encrinus gracilis*.

Quenstedt also figures several cases of abnormal development of the arm tips, in which the suddenly constricted apices are uniserial. (Loc. cit., figs. 175 and 181.)

Platycrinus.

Wachsmuth and Springer figure a young *Platycrinus americanus* (N. A. Camer. Crinoidea, pl. 75. fig. 11) in which the arm joints are long and slender, with a uniserial arrangement throughout and wavy in outline. In adults of the same species the arms are biserial, except for a few joints near the calyx, the lowest of which are rectangular. Upward, these pass into wedge-shaped plates by a gradual transition. But the transition from uniserial cuneate to interlocking biserial plates is quite abrupt.

Young specimens of *Platycrinus huntsvillæ* (Troost) from the St. Louis group of Huntsville, Alabama, show uniseriality throughout. The arm represented in fig. 3 is almost 9^{mm} long. There are thirteen joints including the basal one, i. e., the first brachial; and all are more or less rectangular and much longer than wide. The cuneate stage, through which most of these joints will pass, is suggested by the manner in which the plates bulge on the pinnulate side. The pinnules at this stage are relatively large, having more the aspect of branches.

A somewhat older specimen is shown in fig. 4, the length of the arm being 12^{mm}. The 8th plate has become more wedge-like than the preceding ones, and the 9th, 10th, and 11th are regularly cuneate. Plates 12 to 21 represent the biserial stage, the first and last of these being transitional. Plate 22, however, is a uniserial cuneate plate, and so are plates 23 and 24. Plate 25 is truncated, while 27 is rectangular. It is thus seen that the biserial plates do not appear as such after that stage in development has been reached, as held by Wachsmuth and Springer; but that the newly formed plates at the apex are uniserial and rectangular, and gradually change through cuneate to a biserial interlocking condition.

In the adult of this species (fig. 5) the biserial condition has been pushed down to the 8th plate, while plates 7 and 8 have become cuneate. But somewhat more retarded individuals have been observed which, though of adult size, had eight and even nine uniserial plates at the base of the arm. A single specimen was found in which eleven uniserial plates occurred at the base of the arm, though the upper two or three were strongly cuneate and of a transitional character.

Two specimens of *Platycrinus hemisphericus* from the Keokuk of Crawfordsville have the arms shown in figures 6 and 7. In this species there are five groups of arms, each consisting of six or eight arms. Fig. 6 represents the second arm from the right, of a group of six, this arm becoming free above the fifth brachial. There are about thirteen brachials

of this arm uniserial; i. e., up to and including the 18th arm plate. After this, biserial conditions prevail to the 103d plate, which is cuneate and uniserial. Then the plates become more and more truncated, until the 110th plate is nearly rectangular. In this species, according to Wachsmuth and Springer, biseriality appears late in life. They cite a specimen in which the crown measures 22^{mm} while the arms are still uniserial to the tips.*

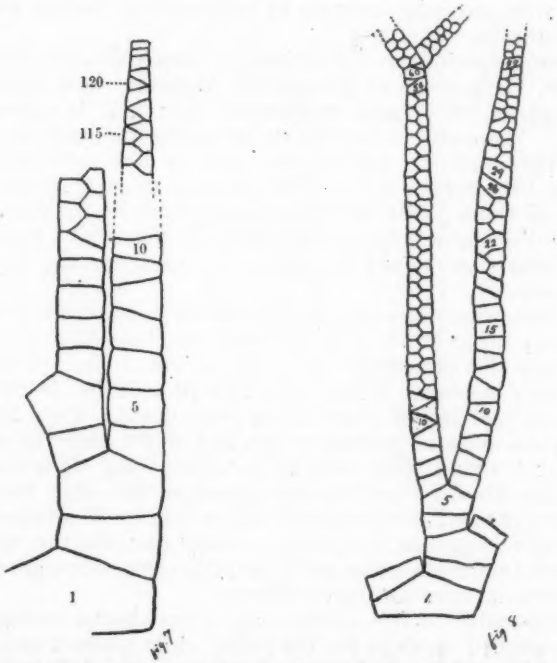

FIG. 7. Platycrinus hemisphericus. Diagram of part of group showing character of plates. (Harv. Univ. Pal. Lab. Coll.)

FIG. 8. Platycrinus hemisphericus. Diagram of two arms showing great irregularity in plates, and a bifurcation. (U. S. Nat. Mus. Coll.)

Fig. 7 represents the outer arm of a group of six in another specimen. The transition plates from uniserial to biserial at the base are broken away, but there are at least eight or nine of the uniserial ones. After that (from about the thirteenth plate from the base of the group) biserial conditions obtain through the 117th plate, after which the plates are again uniserial. An irregularity occurs in plate 119, which is

*Loc. cit., p. 704.

enlarged so as to occupy the place of two plates. The last three plates of the arm are rectangular.

A specimen of *P. hemisphericus* in the collection of the National Museum (cat. 24,183) shows some very interesting abnormal features. Fig. 8 represents two out of a group of six arms. In the right hand member represented, uniserial conditions obtain to the 18th plate. While most of these plates are more or less cuneate, some rectangular ones are interspersed. These apparently retain their primitive condition. Biseriality begins abruptly with the 19th plate. The 22d plate is a double one, or, at least, occupies the place of two. It has either retained its primitive character or developed at the expense of another plate, which became abortive. The same thing holds true of plates 28 and 29. These seem to be primitive plates. Plate 35 is developed at the expense of plate 36. Number 47 is again a uniserial plate. The terminal plates are not well enough preserved to determine their character. The next adjoining arm has seven uniserial plates; i. e., to the 12th plate of the arm. This and the two preceding ones are regularly cuneate. Above this, biseriality commences abruptly and continues uniformly through plate 57. Plates 58 and 60 appear abruptly as uniserial plates with plate 59 wedged in between them. Above plate 61 the arm divides into two branches, the left branch continuing normally biserial, the right one beginning with a uniserial plate. The terminal portions of these branches are not preserved. The same specimen shows another bifurcating arm, and several more arms with uniserial plates interspersed. Perfect specimens of this species always show the uniserial terminal plates, so far as I know; this species being, next to *Encrinus liliiformis*, one of the best to show this feature.

Dichocrinus inornatus W. and S.

This species from the Kinderhook of Marshall Co., Iowa (National Museum collection), has three uniserial plates at the base of the arm above the first division. After that the plates become biserial. In the arm represented in fig. 9 the 84th plate from the base has become biserial, while from the 85th upwards uniserial conditions still persist. In this arm, the apex of which is broken away, nine uniserial plates persist, the topmost one having passed but little beyond rectangular form. In a more perfect arm of the same specimen (fig. 10) twenty uniserial plates occur at the apex, the lower of which are cuneate, while the upper closely approach rectangularity.

In Wachsmuth and Springer's figure of the type specimen of *Dichocrinus hamiltonensis* Worthen* the apical plates of

*Loc. cit., pl. 76, fig. 10.

the arm are represented as uniserial. As nearly as can be determined from the figure, there are fourteen uniserial plates above the biserial ones. The lower are cuneate, the uppermost quadrangular. In the text the arms are stated to be "composed of long, cuneate plates, which slightly interlock." I have not seen this specimen, but it is highly probable that Mr. Westergren's figure of it represents the true characters.

Acrocrinus amphora W. and S.

A specimen of this rare species from the St. Louis of Huntsville, Alabama, in the collection of Mr. E. G. Kirk, has an unusually well preserved arm. Eighteen or nineteen of the terminal plates of this arm are uniserial; the apical one is

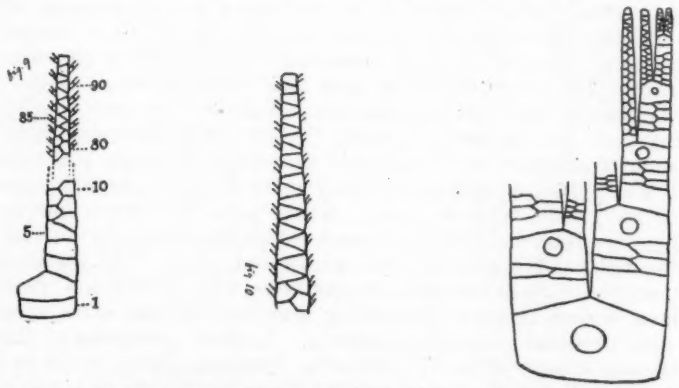

FIG. 9. Dichocrinus inornatus. Diagram of arm showing terminal uniserial plates. (U. S. Nat. Mus. Coll.)

FIG. 10. Dichocrinus inornatus. Diagram of apex of arm showing numerous uniserial plates. (U. S. Nat. Mus. Coll.)

FIG. 11. Hydreionocrinus depressus. Diagram of part of an arm group, showing mode of branching, and terminal uniserial plates. (Kirk Coll.)

quadrangular, the one next below nearly so. The third and fourth from the tip are slightly truncate, the fifth to eighth cuneate, and the ninth to eighteenth cuneate with the point of the wedge extremely thin and slender, but extending entirely across. The nineteenth to twenty-first from the tip mark the transition from the uniserial to the biserial.

Zeacrinus commaticus Miller.

This species is normally uniserial throughout. Specimens from the Warsaw limestone of Boonville, Mo., show an approach to biseriality in a few of the adult plates, which do not extend entirely across, so that the two cuneate plates of the same side

are in contact for a short distance. Normally, in the adult, the plates of the arm above the middle are cuneate, but above this they are again rectangular to the tip. This cuneate character of plates is much less marked and often wanting entirely on young individuals.

Eucalyptocrinus ovalis Hall.

In a young specimen of this species from the Niagara of Waldron, Ind., the terminal plates, though not quite clearly defined, appear to extend entirely across. They furthermore seem to be cuneate to the tip. It thus seems that this species has its terminal arm plates introduced in cuneate form.

Hydreionocrinus depressus (Troost).

This species from the Chester of Sloans Valley, Ky. (Kirk Coll.), is remarkable for the curious development of its arm plates. (Fig. 11.) The first brachial is large, spine-bearing and axillary. Upon this follows on each side a simple, nearly rectangular plate, each followed in turn by one or two sets of interlocking or biserial plates. This is again followed by a single spinous axillary plate, which is in its turn succeeded on each upper face by a single large plate. On the inner branches a large number of biserial plates follow immediately upon this plate, continuing to near the apices of the arms, where they become uniserial, with rectangular terminal plates. The outer arms branch again, only a few biserial plates intervening between the first plate and the simple spinous axillary of the new division. The inner one of the branches is again simple, with biserial plates, uniserial at the apex; while the outer arm, after a few biserial plates, branches again, making the fourth division. Again the inner arm continues simple, with biserial plates changing above into uniserial, with quadrangular terminal plates. A final division, the fifth, occurs in the outer arm after a biserial interval. Each of the final divisions is biserial at first, but uniserial at the apex. It may be noted that as we proceed upwards an increasing number of biserial plates intervenes between the base of a branch and its division.

We have now seen that in the representatives of the three most important orders of crinoids, the Articulata, the Camerata, and the Fistulata, the terminal arm plates are introduced as uniserial quadrangular ossicles, which later change to cuneate and finally to a biserial interlocking condition. It may therefore be considered as highly probable that all arm plates are normally introduced as quadrangular plates in a uniserial condition. In primitive forms they never pass beyond that condition. In more specialized types the earliest arm plates alone

remain in that state, the later added ones passing beyond this stage into a cuneate condition. In still more specialized types the later added plates are endowed with potential biseriality, which appears in the development after the youthful condition is passed. In accelerated types earlier and earlier plates are thus endowed, the biserial condition appearing in them in the inverse order of their age, until only the oldest one or two remain uniserial. It is to be expected that in old age individuals this endowment with potential biseriality is weakened, or perhaps absent altogether, in which case gerontic individuals would permanently remain uniserial. From this we might argue that phylogerontic types would have permanently uniserial plates in the normal adult; and thus, carrying the argument to its logical conclusion, we may have in extreme phylogerontic types uniserial plates in the greater part or the whole of the arm, even though biserial conditions obtained in ancestral types. Phylogerontic types may have biserial conditions begin very early in the adult individual, while at the same time a large number of uniserial plates are found at the summit of the arm. *Dichocrinus inornatus* (figs. 9 and 10) may possibly serve as an illustration of this. On the other hand, we may expect primitive types to have a large number of uniserial plates at the base of the arm in the adult, while at the tip of the arm only a few uniserial plates would exist at any time.

In adults of acmic types only a few uniserial plates, or none at all, should exist at the base of the arm, while at the summit, likewise, very few uniserial plates are to be looked for. In fact, it is not difficult to conceive that in highly accelerated types the newly introduced plate may be cuneate if not biserial from the beginning. For examples of this we must look among the highly accelerated Actinocrinidæ and Batocrinidæ.

While a uniserial apex in a biserial arm *may* represent old age conditions in the individual or the race, as well as a pathologic state, it does not always represent this. For uniserial apical conditions have been found in individuals of all ages, even young ones, so that it is perfectly clear that normally a uniserial character of an apical plate indicates the youth of that plate, and only secondarily the old age conditions of the individual.

Paleontological Laboratory,
Columbia University.

Art. XXIX.—*Notes on the Geology of the Hawaiian Islands;* by J. C. Branner. (With Plate XV.)

Introduction.—The few notes I was able to make during a recent visit to Hawaii are necessarily fragmentary, but our knowledge of the geology of these islands is so strictly confined to volcanic phenomena that I venture to publish these facts for what they are worth.

It is much to be hoped that the territory will make early provision for a geological study of the group. A modest territorial survey could be readily and cheaply carried on in connection with either the government survey or with the Bishop Museum at Honolulu. Such a survey could bring together illustrative material of the greatest scientific importance and educational value, and it would reflect great credit upon the intelligence of the people of the islands.

The canyons on the north side of Hawaii.—One of the most striking features of the island of Hawaii is the series of canyons on the northern coast of the island. These gorges are mentioned by Dutton,* but he says nothing further of them than that they are valleys of erosion.

One of the most striking things about them is that as one sails round the extreme north end of the island the coast bluffs are low—averaging less than a hundred feet—and the land but little broken and under cultivation. Suddenly there is an abrupt change in the coast topography: the bluffs facing the area have an elevation of a thousand feet, and enormous gorges extend inland with almost perpendicular walls, some of which it is said are as much as 2,000 feet in height. These gorges, great and small, continue for twelve miles along the coast, where they end as suddenly as they began, against comparatively smooth arable lands. The region of gorges is covered with forests, and, save in the flat valleys, is not cultivated. The gorges extend back inland for five or six miles, in the direction of the cluster of highlands near Waimea Village. The summit of this cluster is reported to be 5,505 feet high. One of the remarkable features of these valleys is the fact that they are nearly or quite as deep at or near their upper ends as they are at their lower ends. Another striking feature is that the largest of them have flat bottoms.

This deeply eroded part receives no more rain than the adjacent areas north and south of it, and the difference in topography is due, I believe, to the difference in age between

* Hawaiian Volcanoes. By C. E. Dutton. Fourth Ann. Report U. S. Geological Survey, 1882–83, pp. 75–219. Washington, 1884.

the different portions of the island. Lava flows from Mouna Kea have encroached upon this eroded region from the south,

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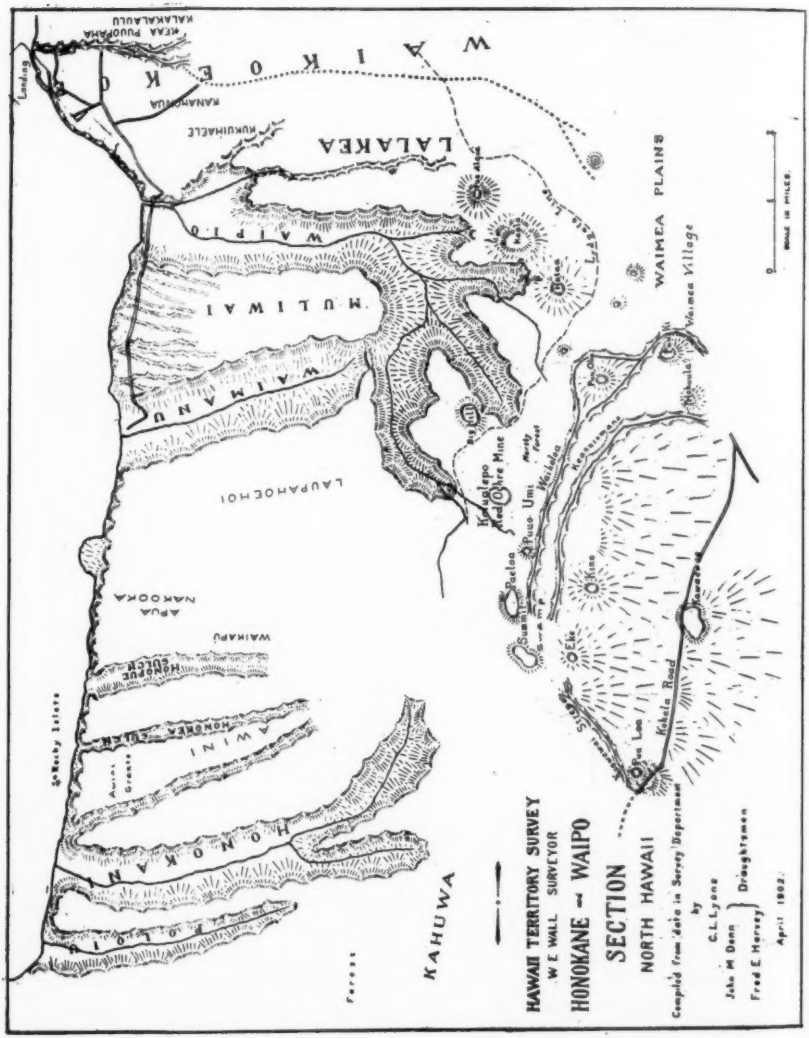

burying the lower and more eroded land surfaces, while on the north similar flows have likewise encroached upon that side.

The great height of the sea bluffs is due to the long encroachment of the sea upon this old land margin. The flat bottoms of the largest of these canyons are due to the fact that the canyons were formed as V-shaped gorges on the land and have sunk until their lower ends were filled by the sea, forming deep fjords which were soon filled by the material cut by the waves from the headlands and thrown back into them, and by the debris brought down from the land by the streams. An approximate idea of the depression might be obtained by borings in the lower ends of these valleys. I am unable to learn of any deep wells having been put down in them. The accompanying photograph (fig. 2) gives some idea of the striking topography of the Waipio Valley, the largest of the group.

Professor W. T. Brigham, the able director of the Bishop Museum at Honolulu, tells me that there are precisely similar valleys on the north side of the island of Kauai. An assistant in the office of the government surveyor at Honolulu, who has lately visited the region, also states that the bluffs on that part of Kauai are from 1,000 to 1,500 feet high, and that some of these valleys are flat-bottomed while others are V-shaped and truncated above tide level.

The origin of Pearl Harbor (Plate XV).*—The topography of Pearl Harbor is so different from that of most harbors that it is sometimes spoken of as being unusual and difficult of explanation.

Briefly, this harbor has been formed by the depression beneath the sea of a small group of dendritic valleys previously carved by subaerial erosion in horizontal beds of rocks. If this explanation is not at once suggested by a glance at the map, it is made quite plain by a brief study of the rocks exposed about the harbor. The rocks are horizontal and consist of alternate beds of volcanic tuff and coral rocks. The so-called coral rocks, however, are not necessarily all of coral but are often mixtures of shells and other fragmental calcareous materials commonly found in and about coral reefs.

The low bluffs that surround the harbor are nearly all horizontal beds of tuff. Coral rocks are shown on the government map of the harbor at a few places. Those particular points I did not examine, but there is no reason for doubting this identification of the rock, for a few miles east of the harbor the coral rocks are exposed ten or more feet above tide level. In the wells put down in the vicinity of the harbor the coral rock is also found a very short distance below tide level.

The harbor is now quite shallow over most of its area, but this shallowness is due to the silts having been washed down

*The explanation here given was presented before the Social Science Association of Honolulu in March, 1903.

The Waipio Valley looking up the valley from near the sea shore.

from the surrounding land and deposited in the harbor's quiet waters. In the first edition of his work upon volcanoes Dana says (p. 282) that it would be necessary to cut a channel through the outer reef in order to make a harbor of this place. Later it has been found that there is a natural opening quite through the reef, and dredging is now going on to remove the bar of sand just outside of the narrow entrance. The shallowness of the water outside and its greater depth in the neck of the harbor is caused by tidal scour.

The depth of the silts in the harbor has probably been determined, but I have not been able thus far to get any information on this subject. The topography and geology offer no suggestion further than that the depth is likely to be approximately the same as that of the harbor at Honolulu, that is, about thirty feet. The depth of the silts can be readily determined by driving steel rods down into them.

We shall readily understand the process by which this topography was made if we imagine the whole island elevated fifty or seventy-five feet and the original rock-beds restored right across the present channels. We should then have the streams that now enter the upper parts of Pearl Harbor flowing across a table land of horizontal rocks, uniting at or near the point marked A on the map and entering the sea below the boat landing through a single channel. In the course of time these streams would all cut steep-sided gorges, and where the gorges, by bends of the streams, approached each other the watershed between the two streams would be lowered below the general land surface. Such a place would eventually be an isolated bit of high land and after depression would form an island, such as we have in Mokuumeume. A depression of the island would back the sea into the valleys; the cutting of the streams would then cease, and the land silts would settle in the quiet water of the submerged channels, forming shallows, later mud-flats, and then the swampy lands.

The map of the island (see Plate XV) shows that the entrance to Pearl Harbor through the coral reef is very like that opening into the harbor of Honolulu and like another similar one known as the Kalihi entrance about two miles east of the Honolulu harbor. It seems probable, therefore, that all three of these harbors and their passages through the coral reef have been formed in the same way.

Aside from the form of Pearl Harbor there is evidence of depression of Oahu and the other islands of this group. The evidence of depression on Oahu consists partly of the great depth at which coral rock has been found in deep wells; some of the evidence on the island of Hawaii is mentioned in the preceding note upon the Waipio and other canyons.

The east base of Diamond Head.—In an article published in vol. xi of the Bulletin of the Geological Society of America, pp. 57–60, Dr. Dall speaks of certain beds at the base of Diamond Head on the island of Oahu. It is possible that my own observations about the eastern base of that mountain were not made upon the same beds as those spoken of by Dr. Dall, but as nearly as I can make out from the text of his article, the beds are the same. If so I do not agree with some of his conclusions in regard to geologic structure. He says: "It (Diamond Head) is composed of horizontal layers of tuff, interstratified with thin layers of calcareous sand, the lime from which, leached out by the rain, is redeposited in a thin superficial crust of a brilliant white, giving the effect, among the

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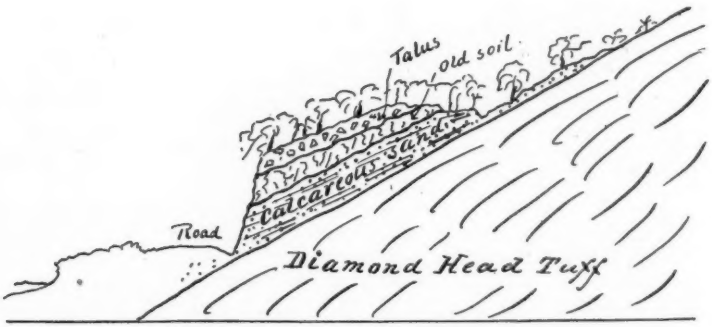

The section exposed beside the road at the southwest base of Diamond Head.

sparse arid vegetation, of a thin layer of snow. The strata of the head have not the 'onion peel' aspect of layers of successive subaerial eruptions, but are strictly horizontal and have every aspect of having been deposited in water. . . . . My observation was not carried to a point more than 100 feet above the sea-level, but it is evident that the sand layers occur, interstratified in the mass, clear to the top (700 feet). The upper limy layers appear, so far as observed, to be composed almost entirely of calcareous sand, and no shells or corals were observed in them in a recognizable state. At about 50 feet above the sea the heavy tuffs overlie the uppermost heavy layers of calcareous rock. The latter is nearly or quite horizontal, and consists of coral-sand grains more or less compactly consolidated, with occasional patches where marine fossil shells were abundant. There are hardly traces of coral larger than fine gravel and no coral masses."

Calcareous beds like those mentioned by Dr. Dall are exposed along the road leading from Waikiki beach past the lighthouse, and these beds appear to be horizontal. This appearance of horizontality, however, is deceptive and is due to the direction of the sections cut along the road. The beds are mostly calcareous sands dipping seaward an angle of from thirty to thirty-two degrees. (The highest angle of dry sand is thirty-five degrees.) The accompanying photograph shows the bedding fairly well. These beds are about fifteen feet thick at this place, and it is my opinion that they are old sand dunes that were blown up from the beach against the eastern flank of Diamond Head after the crater ceased to be active. In any case, these sands rest directly upon the Diamond Head tuffs, and are overlain by an old soil containing fossil plants, and by talus derived from the breaking up of the tuffs of the upper part of Diamond Head. The beach was farther north when these sands were blown up than it is now, for the waves have long been cutting away and encroaching upon the land.

The talus along this same road and near the lighthouse at the base of Diamond Head deserves a word. This talus for the most part has the same dip as the tuffs beneath them, but here and there they are horizontal for a short distance. Nearly all of them, however, appear to be horizontal owing to an angle at which they are cut by the road. This appearance of horizontality, therefore, is deceptive. The talus deposits are probably as much as thirty feet thick at and near the quarry south of the lighthouse. It is evident, however, that if they were really horizontal, as they were regarded by Dr. Dall, they would have a much greater thickness than they really have. The talus beds contain scattered throughout them a great many fossil shells. These shells are sometimes found in old soil layers, but they are found in almost every part of the materials, even among the loose, open angular rock fragments. These fossils are land shells. Whether they are living forms I did not ascertain. The animals have died, have fallen on the surface, and have eventually been buried by talus sliding down the steep slopes of Diamond Head. It is to these that Dr. Dall seems to refer when he says the tuffs, i. e. the talus beds, overlie the calcareous rock.

Since the above was written I have seen an article published (American Geologist, Jan., 1901) by Mr. S. E. Bishop of Honolulu in which he also disagrees with Dr. Dall in regard to the origin of the calcareous sand. He says that it is aeolian, and he accounts for the shells in the same way as the writer. I do not agree with either Mr. Dall or Mr. Bishop about the tuffs of Diamond Head having been deposited in shallow water. I think they are all land deposits; at least I

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Aeolian sandstone at the east base of Diamond Head, Honolulu.

see no reason why they may not have been deposited on land, for in structure and contents they are similar to the other cinder cones on this and other islands of the Hawaiian group.

Cirques.—On the sides of Diamond Head near the top are many small cirques that throw light upon the origin of these topographic forms. The beds of tuff at the rim of the crater dipping outward, erosion has cut deep funnel-shaped pits—small cirques—in the outside of the crater. The back walls of these pits are very steep, even vertical or overhanging in the middle. In the development of these cirques or barriers separating two of them disappear and the cirques unite at the top but are separated below by symmetrical cones that form the spurs or ridges that radiate from the main mountain. Such cones are beautifully developed on the east face of Diamond Head. I have tried in vain to represent the cirques of Diamond Head by a diagram. The figure accompanying shows their relation to the edge of the crater on the right.

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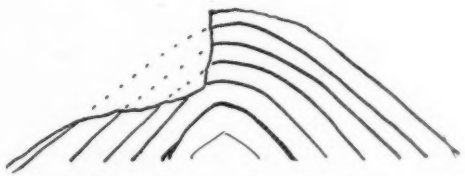

Section through a cirque on the outer rim of a crater.

On the island of Hawaii are several cirques of enormous size. The one shown on the next page and made from a photograph has walls said to be more than a thousand feet high. The upper ends of several of the deep valleys of northern Hawaii appear to have been cirques originally. It should be noted that the rocks both of Hawaii and of Diamond Head on Oahu in which the cirques are cut are of even texture throughout, and that they spall off rapidly in small angular lumps. Those who believe in the glacial origin of cirques find here good evidence that cirques both large and small may be and are formed without the aid of ice.

The craters near the Pali.—Dana mentions (Volcanoes, 2d ed.) the small crater at Pali as probably the last expiring effort of the volcanic phenomena of the island of Oahu. Mr. S. E. Bishop in his interesting paper upon the geology of Oahu, published in the Hawaiian Annual for 1901, also speaks of this crater. It occupies a striking position in relation to the topography of the island. The structural relation of its tuffs are shown by the accompanying sketch (fig. 7). It is clear that this crater

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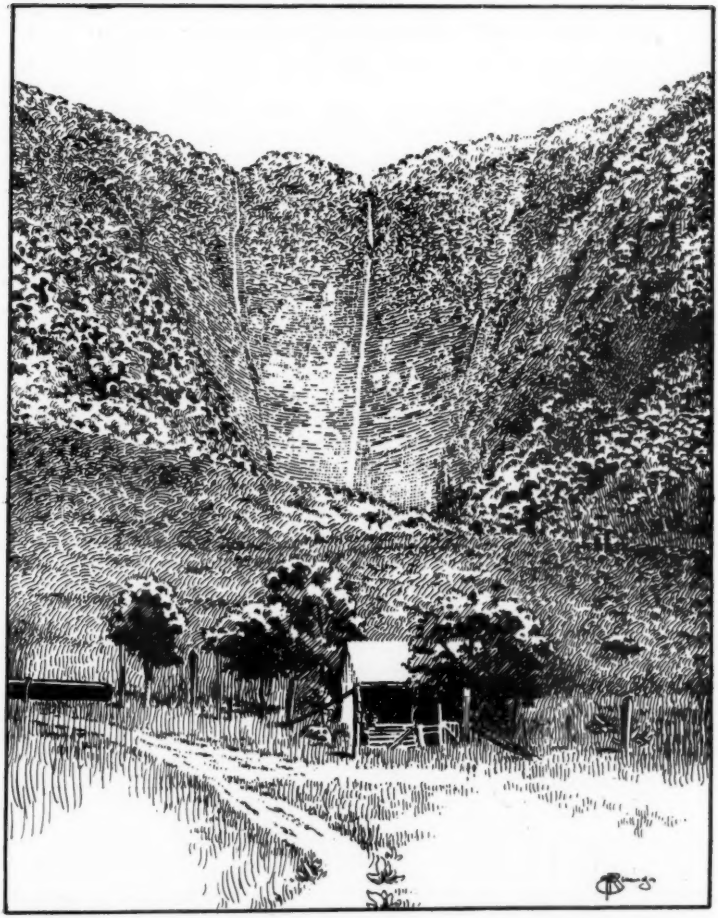

A cirque at the side of Waipio Valley, Island of Hawaii. The wall at the rear is more than a thousand feet high. From a photograph.

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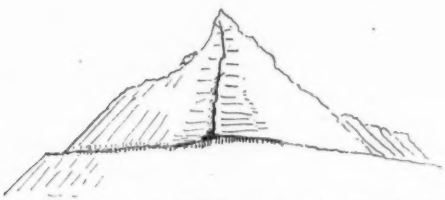
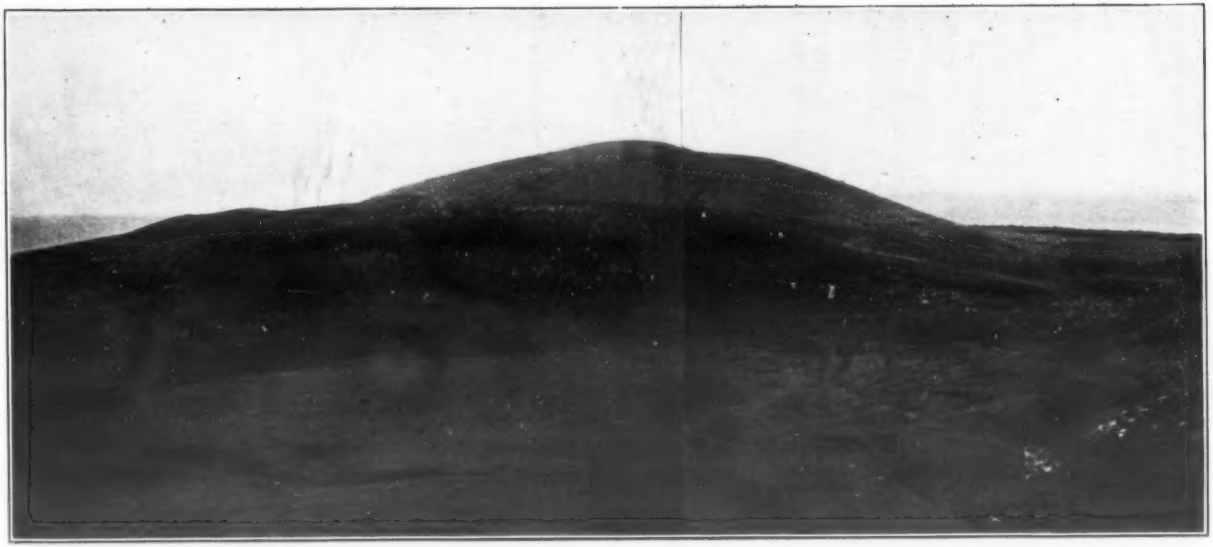


Section above the road at the Pali looking east. The horizontal beds are lavas; the sloping ones are tuffs deposited after the cutting of the steep north face of the Pali.



The Waipio Valley. In the foreground is the small crater just east of Kokohead. The whiteness of the beds is produced by coral fragments in the tuff. Hanauma Bay is just over the ridge and to the left of the highest hill.

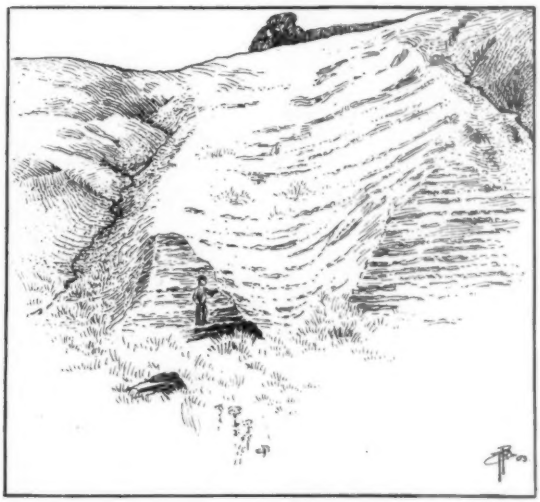
became active after the excavation of the Nuuanu Valley that leads down to the city of Honolulu, and also after the removal of the northern half of the volcanic cone of which these mountains are the remnant, the cinders having fallen upon the steep —almost vertical—face of the bluffs on both sides of the Pali. The road down the north face of the mountain cuts these tuff beds at many places.

The eminence in the Nuuanu Valley on the west side of the road and less than half way from the Pali to Honolulu is also a crater. This crater, also mentioned by Mr. Bishop, is likewise necessarily newer than the Nuuanu Valley in which it is situated. I should add here that I quite agree with Mr. Bishop and with Major Dutton that subaerial erosion is quite competent to explain the more rapid wearing away of the north side of the Pali.

A small crater next to Kokohead.—The most interesting of the small craters examined on Oahu is one at the east base of

Sections exposed on the east side of Kokohead showing old gullies filled with tuff.

the great Kokohead crater at the east end of the island. Its chief interest is in the great quantity of coral blown out and now mingled with its tuffs, and in its age relation to the Kokohead crater. The Kokohead crater is newer than the basalt of the great mountain ranges, for its tuffs overlap the basalt at the west base of Kokohead. The small crater at the east base of Kokohead did not come into existence until Kokohead had ceased to be active and its sides had been deeply scored by erosion. This is shown by the fact that gulches on the east face of Kokohead were filled by the coral-laden materials blown from the smaller crater. These later materials extend half way up to the summit of Kokohead. The accompanying section is made from a photograph of one of these refilled gulches. This line of separation between the two series of tuffs is clearly visible at many places. Aside from the structural relations the two series are readily distinguishable by the great amount of coral and other calcareous materials in the newer while none is recognizable in the older series.



An old gully on the east side of Kokohead filled with tuff from the newer crater. From a photograph by F. E. Harvey.

The deepest part of the smaller crater is now being filled by debris washed down from the east slope of Kokohead. The west side of the small crater is now about 120 feet above the bottom of the pit. This entire wall is made up of tuffs with which are mingled corals, shells and other bits of reef rock. The lumps of coral are sometimes as much as a foot and a half in diameter, but for the most part they are smaller. These bits are usually well preserved and the life forms are readily recognizable. They are rather evenly scattered through the tuffs. The study of these fossils would be of much interest, as it would possibly show the age of the reef through which the crater broke and thus give us another clue to the ages of the various eruptions.

The beds from the smaller crater lap over and form the ridge that separates it from Hanauma Bay. This bay is not the site of a single crater as stated by Dutton,* but of several small ones. It is worthy of note also that the exposure on the sea shore that so closely resembles a section cut through to the middle of a crater is not such a section, but rather the encroachment of the sea upon this group of five or six craters.

* Fourth Ann. Rep. U. S. Geol. Survey, 218.

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Hanauma Bay, the site of several extinct craters.

Well borings on Oahu.—Several records of wells bored for water near Honolulu are given by Dana and Hitchcock.* In addition I have, with the aid of Mr. Fred E. Harvey of the Government Survey, been able to collect several others, and these records, about forty in all, have been plotted to scale for the purpose of attempting a correlation of the beds penetrated. It was found that the characters of the materials passed through as reported are not sufficient to warrant correlation. Herewith are given four of the sections that appear to resemble each other closely. They are all in the city of Honolulu. The enormous quantity of water flowing or being pumped from the wells on Oahu afford a valuable contribution to our knowledge of subterranean waters. It is to be noted that in every instance the wells penetrate beds of coral or other calcareous rocks. These rocks appear to be built round the volcanic core of the islands, but they are sometimes interbedded with lavas, tuffs, or water-worn bowlders. The chief rainfall is in the mountains, but the waters follow down the valleys, sink into porous beds that occupy the lower ends of the valleys and pass seaward as underground waters. It

*Geology of Oahu. Bul. Geol. Soc. Amer., xi, 15–17.

is said that several places are known about the islands where these fresh waters issue beneath the sea.

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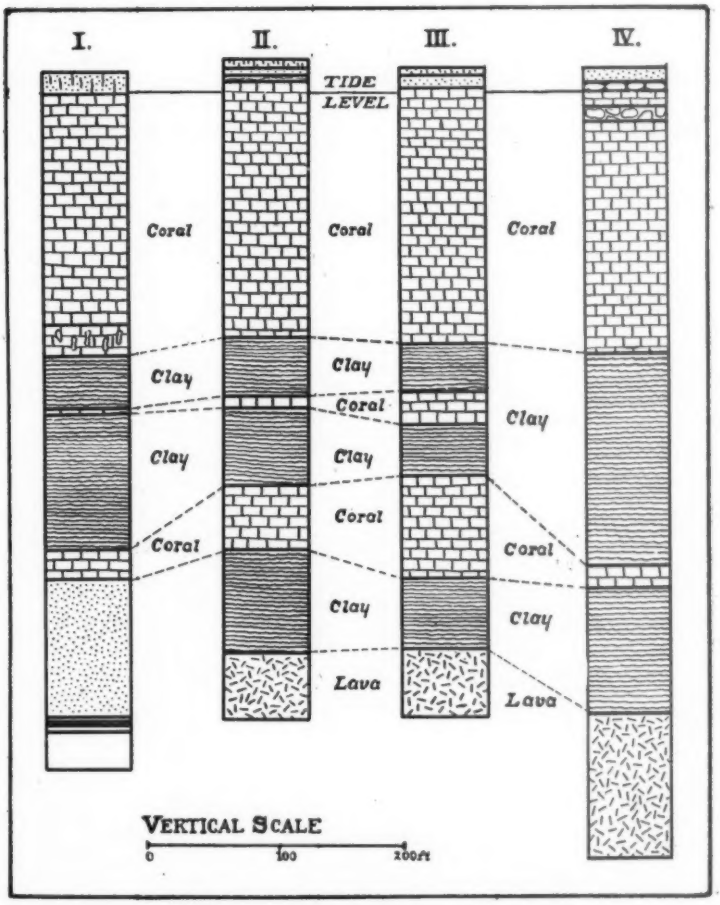
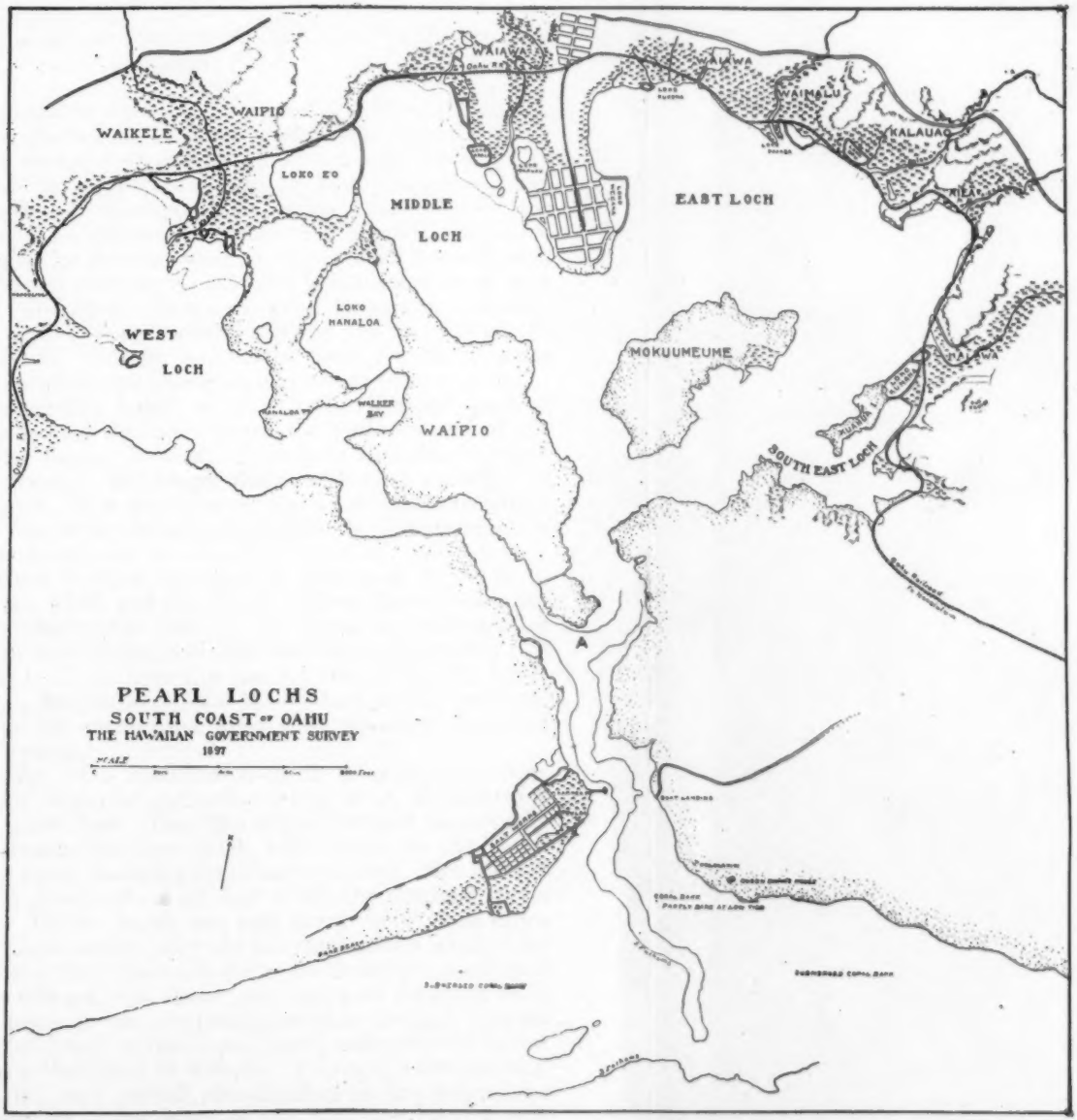


A Group of Well Records in Honolulu.

I. Mrs. Ward's well at Kukuluaeo below King st.
II. Thomas Square well near corner of Beretania and Kapiolani sts.
III. Mr. Sass' well in Kukaokahua ice works.
IV. Pumping Station, corner of Alafai and Beretania sts.

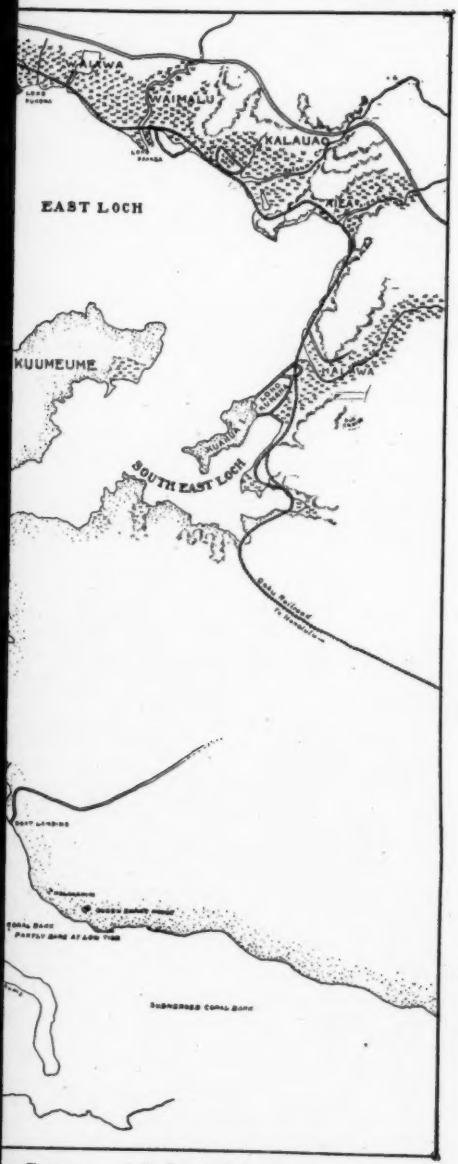
Buried soils.—The tuffs in the vicinity of Salt Lake (west of Honolulu) in many instances fell upon a region covered with forests. This is shown by the tuffs resting directly upon

the old soil surfaces. These soils still retain many root impressions, while at the base of the tuffs are abundant plant fragments preserved as petrifactions. In many places by roadsides and in quarries one may see vertical holes left in the tuffs where the plants have decayed out after being buried. Examples are visible in the new cut opposite Coral Island and in the old cuts near the railway just west of Mr. Dimon's place in Moanalua. In some instances the tree trunks have been petrified and preserved. They often show branches of the plants. The largest trunks seen were about four inches in diameter.



Map of Pearl Harbor or Pearl Lochs near Honolulu. From the Government Survey's latest maps.

Plate XV.



ıe Government Survey's latest maps.

Art. XXX.—*Recent Tuffs of the Soufrière, St. Vincent;* by Ernest Howe.

When geologists visited the region of the West Indian volcanoes after the violent eruption a year ago, a detailed study of the vast deposits of ejecta was all but impossible, and in papers which have appeared during the year, writers have confined themselves to descriptions of varied phenomena of the eruptions and to discussions of complex physical problems. Matters which for the time were of less general interest, such as the forms and character of the new deposits, were to a large extent left untouched. It was my good fortune in February last to be able to spend several days in the vicinity of the Soufrière in St. Vincent, and while there, to study under favorable conditions the enormous deposits of recent ejecta.

Geography.—The Island of St. Vincent lies just north of the Grenadines and Grenada toward the southern end of the chain of the Lesser Antilles. It is about 18 miles in length and 11 in breadth, the longer diameter having a north and south direction. It is wholly mountainous, several peaks rising over 3,500 feet above the sea, and before the last outbreak of the volcano the interior was everywhere densely wooded.

The northern third of the island is dominated by the Soufrière, between which and the abrupt cliffs of Morne Garu, the northern outlier of the hills to the south, is a well marked depression or pass leading from the eastern to the western side of the island. It is from this pass northward that the havoc was wrought, the rampart of the Morne Garu having protected the lands to the south from more than relatively slight and temporary damage.

Topography.—The Soufrière rises on all sides, with even, constructional slopes of rather low angle, to an altitude of a little over 4,000 feet. The sides of the hill have been deeply eroded by streams that have eaten back almost to the crater rim, leaving sharp, radiating spurs between them, the crests of which are in places a thousand feet above the stream-beds on either side. To the north and west abrupt cliffs look down upon the present crater; they are the remains of a much older crater-wall that Drs. Flett and Anderson have aptly compared with Monte Somma. In times past recurrent eruptions have obliterated more or less completely previous drainage systems and presented fresh initial slopes, partly controlled by earlier sculpturing, to the attack of streams. Taking this into account, as well as the only partial consolidation of the fragmental rocks, the erosion of the slopes of the Soufrière may be considered to have advanced into late youth or early maturity.

The devastated area has been admirably described by various writers, notably Drs. Anderson and Flett, in their report to the Royal Society,* and Dr. E. O. Hovey,† and a further description would involve unnecessary repetition.

The bolder forms of the consequent drainage which had been developed on the slopes of the Soufrière have been little changed as a result of the recent eruptions. Changes that have taken place are due less to the new material thrown out than to the abnormal erosion resulting from the complete removal of vegetation and the unusually heavy rains following eruptions. The effects of this erosion are naturally best observed in the areas adjoining the larger streams near their mouths. Directly after the great eruptions the valleys of the Wallibou and Rozeau Dry rivers were almost completely filled in their lower portions with the ejected material from the Soufrière, and about a mile back from the coast these accumulations were nearly a hundred feet in depth, according to the accounts of many who saw them soon after the eruptions, and my own observations some months later confirmed these estimates. From the regions of maximum accumulation there was a gradual decrease in thickness towards the mouths of the rivers, where landslides occurred, leaving cliffs of the older and younger tuffs not more than 20 feet high. The old drainage systems were still sufficiently well marked to direct the new streams that were at once formed, and these began actively to attack the new deposits, with the result that at the time of my visit there had been developed a miniature system of canyons which showed in their nearly vertical walls excellent sections of recent deposits.

Recent deposits.—The ejecta of the recent eruptions now occur in formations of three distinct types, with characters directly related to their modes of origin. The composition of all of them is essentially the same and corresponds closely to that of some of the larger ejected blocks, which appear to be basalts, rich in plagioclase. The material varies from the finest powder to blocks of massive rock several feet in diameter, the most abundant being a coarse sand in which broken crystals of plagioclase, augite and a little hornblende may be distinguished. In the great eruption of September considerable pumice was thrown out, hardly any of which is to be found in the earlier deposits.

The most conspicuous deposits and probably the oldest are

*Preliminary Report on the Recent Eruption of the Soufrière in St. Vincent, and of a visit to Mount Pelée, in Martinique. Proc. Royal Soc., vol. 70, pp. 423–445. London, 1902.

†Martinique and St. Vincent: A Preliminary Report upon the Eruptions of 1902. Bull. Am. Mus. Nat. Hist., vol. xvi, Art. 26, pp. 333–372, 1902. This Journal (4) xiv, 319–359.

the valley fillings. Hovey says of them: "The chief of these beds were formed in the Wallibou, Trespé and Rozeau valleys, on the leeward (west) side, and in the valleys of the Rabaka Dry River and its tributaries, on the windward (east) slope, with by far the greatest thickness along the Wallibou and Rabaka Dry rivers. In the valley of the Wallibou the deposits were not less than 60 feet deep in places, while in the Rabaka Dry River the fresh material filled a gorge which is said to have been 200 feet deep before the eruptions began."* These tuffs, now well exposed in typical "bad-land" topography, consist of a mixture of clay and fine grit, with numerous coarser, angular rock fragments seldom larger than a clenched fist. The prevailing color is a bluish gray where they are moist, but some deposits of the September eruption, still hot and causing secondary steam eruptions, are of a light reddish brown or straw color. The ejecta of repeated eruptions, accumulating layer upon layer, have produced a fairly well marked stratification in these beds, the individual strata, for the most part, consisting of unassorted materials.

Resting in places upon the deposits just described, and everywhere covering the hillsides and ridges, are accumulations of quite a different kind, ranging in thickness from a few inches to five or six feet. They are in all cases distinctly stratified and extremely uniform in character. The lower portions consist of typical unconsolidated lapilli, slightly coarser than peas and becoming smaller in size upward, and mixed with a fine sand until the top layer of the finest dust is reached, the line between the two sorts of materials always being a sharp one. This upper member has been converted into mud by the rains and has subsequently hardened into a firm crust, two to six inches thick, which protects the unconsolidated material below. On close examination, this crust is found to consist of numerous layers or overlapping lenses made up of small pellets of clay as large as buck-shot, closely packed, but not mashed, together. When not too crumbling, portions may be removed whose structure at once suggests that of an oolitic limestone. Material of precisely the same character was collected from the tuffs of Montserrat, and I was told that similar layers have been found in the older deposits of St. Vincent. Last summer, at the crater rim of Kilauea in the Hawaiian Islands, Dr. Whitman Cross collected a quantity of pellets, which differ in no way from those that came from St. Vincent. This structure would seem to be explained by the fact that at the time of violent eruptions, and after the fall of the coarser material, particles of dust still held in suspension would be attracted to the globules of condensing steam, which, on fall-

*Op. cit., p. 342.

ing, would accumulate more and more of the fine material, until, on reaching the ground, they would be in the form of hard clay pellets. When I visited the crater, such drops, although much diluted, were falling almost continuously, following the small intermittent eruptions of steam and mud that were taking place from time to time. Flett and Anderson make reference to the same phenomenon in speaking of the Soufrière. They say: "Before midday there had been very heavy rain-showers, and it was noticed that the rain-drops carried down fine particles of ash."* And again, in describing the eruption of Pelée, which they witnessed: "In a minute or two fine, grey ash, moist and clinging together in small globules, poured down upon us. After that for some time there was a rain of dry, grey ashes."†

It may not be out of place to suggest here that this globular oolitic structure might be looked for in older tuffs in other parts of the world, as for example, in the great Tertiary deposits of the Rocky Mountains, and that its occurrence might serve as a means of indicating the proximity of the vent from which the breccias and tuffs were derived, since from the nature of their origin, deposits of this character could not occur at any great distances from the source of supply.

The third kind of deposit is stream-laid volcanic debris in the bottoms of the canyons near where they empty into the sea. This is in all probability largely composed of recent ejecta, but there is considerable old material mixed with it, such as fragments removed from the older tuffs exposed by erosion. These fluviatile deposits are only prominent near the mouths of the larger streams, and are hardly to be separated from the submarine deltas where an enormous quantity of material has been laid down. Unfortunately nothing is known of the changes in depth that have taken place along the coastline, nor of the effect of coastal landslips that continued to take place for some time after eruptions. These fluviatile deposits, plainly due to the overloading of the streams during the rainy season, are of only relative importance in St. Vincent, and the chances are that after another period of heavy rains only faint traces of them will be left. They are of interest, however, for purposes of comparison with tuffs of other regions, where similar deposits should be found, and where, on account of included fragments of older rocks, the actual age relations with other tuffs of the same series of eruptions might be misinterpreted. They are obviously the youngest deposits in St. Vincent.

Where fresh sections of the older and younger tuffs have been exposed by landslips from the ends of small spurs and

* Op. cit., p. 428. † Op. cit., p. 443.

ridges, along the coast, an interesting structure is brought out. Deposits of the second kind, following as they do the rolling surfaces of the ridges and sides of the spurs, appear to have been compressed into a series of anticlinal folds. Precisely this structure occurs in the sea-cliffs about one mile south of Basse Terre, Guadeloupe, where the unconformable relations with the underlying beds are obscured and the pseudo-folding most perfect and deceptive.

Mode of Origin.—Whatever interest the deposits may have depends very largely upon their mode of origin, and in regard to this there is considerable trustworthy information.

The events attending the first eruption of the Soufrière, as reported by eye-witnesses, may be briefly summarized as follows:

On Wednesday, May 7, 1902, explosions occurred and vast clouds of steam rose from the Soufrière, but no damage was done, and only a film of fine dust was noticed on the leaves of the trees on the lower slopes. Almost at the same time, streams such as the Wallibou and Rabaka became raging torrents of hot, muddy water, probably due to the overflow of crater lake. According to information which I received from several persons who witnessed the eruptions, no mud-flows occurred, and I could find no evidence in the deposits themselves to show that they had descended directly from the crater as mud streams. Doubtless these torrents scoured their stream-beds clean, and possibly removed a little soil and vegetation, but brought about no marked changes. It was not until the early afternoon of this same day that the eruptions reached destructive violence, when an enormous black cloud, "laden with hot dust, swept with terrific velocity down the mountain-side, burying the country in hot sand, suffocating and burning all living creatures in its path, and devouring the rich vegetation of the hill with one burning blast."* Although added to by subsequent violent eruptions, it was at this time that the great tuff beds in the valleys were formed. The exact nature of this "down-blast" may not be clearly understood as yet, but the fact of its occurrence in St. Vincent and of a similar one in Martinique cannot be questioned. Briefly, its effect was to sweep the ridges clean and to fill the ravines and valleys with the enormous quantities of hot dust and lapilli with which it was charged, in the same way that depressions and spots protected from the wind are filled with great drifts of snow by a driving storm. Deep deposits did not occur in the upper portions of the ravines, since they radiated from the crater and lay directly in the line of the blast, which could sweep them

*Anderson and Flett, op. cit., p. 427.

as clean as the ridges. It was only in the lower valleys, whose directions were more or less transverse to that of the blast, that great accumulations of ejecta were formed. Following this blast came a fall of lapilli and dust from clouds that had been carried upward, and not until then were the ridges and upper ravines covered with new material to an appreciable extent.

In all probability these events did not take place in as simple a manner as has been indicated, but were complicated by repeated eruptions of greater or less intensity, but which would hardly modify the general relations of the two deposits. What did undoubtedly affect the character of the deposits filling the valleys were torrents, due to the unusual precipitation of rain connected with the eruptions. The action of these streams was very interesting and peculiar and was described in detail by the first observers. The loose and unconsolidated materials were picked up so readily by the torrents that the streams became overloaded and clogged, and dams were formed which soon gave way, permitting a rush of accumulated and partly cleared water to lower portions of the channel, where the process was repeated. Hovey,* in speaking of the Wallibou River, describes how "it cut into and undermined the beds of dust and lapilli along the banks. Its waters became so overloaded with sediment that they could only flow in pulsations, showing that intervals of time were needed by the stream to gather strength to force its way along with its burden." Water was also soaking into the beds of extremely hot ejecta and being converted into steam, which broke forth at intervals with force enough to throw dams across the streams and to divert them from their channels. These processes undoubtedly did much to add to the incoherent character of the valley fillings and to obliterate in many instances their original stratification.

Of the submarine deposits nothing is known. Extensive deltas were developed at the mouths of the larger streams, only to disappear after a brief existence, the angle of the submarine slopes being too great to support the unwonted loads which had been suddenly laid down upon them.

One cannot fail to be impressed by the geological processes that are being carried on at the Soufrière—the ejection and deposition of comminuted rock, the first partial consolidation into stratified tuffs, their erosion, and redeposition on the sea-bottom. For years to come the West Indian volcanoes should continue to be worthy of the detailed study of the general geologist, as well as the petrographer and physicist.

U. S. Geological Survey, Washington, D. C.

*Op. cit., p. 344.

Art. XXXI.—*Discovery of Fossil Insects in the Permian of Kansas;* by E. H. Sellards.

The question of the age of the Upper Paleozoic formations of Kansas has occasioned considerable difference of opinion among geologists and paleontologists. Professor C. S. Prosser, who, among others, has been a thorough student of the problem, in a recent very full review of the evidence from zoöpaleontology and stratigraphy, concludes, in harmony with his earlier results, that "the weight of evidence" favors "correlating the upper formations with the Permian."* In his synopsis of the views of geologists who have written on the subject, however, Professor Prosser makes it evident that this opinion, although perhaps receiving the greatest support, is not unanimous. Any additional paleontological evidence is therefore especially welcome. Until recently the discussion has been confined largely to the marine invertebrates, which unfortunately become extremely rare near the top of the series.

During the summer of 1902 the writer discovered a rich insect locality in the Marion formation, in the southern part of Dickinson county, Kansas. The condition of preservation of the insects is exceptionally good. A very large proportion of the wings are complete and their details of structure clear, even the minute hairs often being present. The entire bodies of the insects are occasionally preserved. A considerable number of insects had been previously obtained from the Coal Measures near Lawrence, Kansas, mostly by the University Geological Survey of Kansas. The insects from the Marion seem on the whole very different from those of the Lawrence shales and other Coal Measure deposits. The Coal Measure insects, as far as known, are on the average large; on the contrary, most of the Marion species are small. Cockroaches at this new locality are much in the minority. Of some six hundred specimens collected, not more than about sixteen are cockroaches and these are of small size and belong for the most part to the Coal Measure and Permian genus *Etoblattina*. Fossil plants were discovered in the Marion in 1899.† The collections made from the Marion and Wellington (?) during 1899–1900 seemed to the writer at that time to indicate a Lower Permian flora.‡ These collections have since been increased, and it may now be said with a good deal of confidence that, although a few species have survived from the Upper Coal Measures, the Marion contains on the whole a dis-

* Journal of Geology, vol. x, p. 728, 1902.

† The occurrence of two specimens of insects among the plants was noted by the writer in connection with the description of the Tæniopterid ferns from this formation (Kansas Univ. Quart., vol. x, p. 11, 1901).

‡ Trans. Kansas Acad. Sci., vol. xvii, p. 208, 1899–1900.

tinctly Permian flora. The marked change in the insect fauna in passing from the Lawrence shales to the Marion formation is therefore paralleled by the plant evolution.

From the biological side the discovery of a productive insect horizon in deposits of Permian age is of the greatest importance. Aside from the cockroaches, the number of insects known from the Permian system is confined to a few interesting specimens. The terrestrial habits of most adult insects, together with their soft bodies, cause them, as a rule, to be rare fossils as compared with marine shelled animals, especially in Paleozoic deposits. The conditions of deposition, however, during the latter part of the Paleozoic seem to have been more favorable for the preservation of insects as well as of plants, and thanks, especially, to the faithful researches of Scudder in this country and of Brongniart and others in Europe, a good deal is now known of Coal Measure insects. The degree of organization of Upper Carboniferous insects indicates a much earlier origin for the class, and their remains, if not already found, may be confidently expected in pre-Carboniferous deposits. Unfortunately there seems to be as yet no unquestioned record of the occurrence of Hexapoda back of the Carboniferous. Insects have been reported from three pre-Carboniferous localities,—Ordovician (Lower Silurian) of Sweden, Middle Silurian of France, and Devonian of Canada. Regarding the Ordovician fossil, Professor Moberg with commendable frankness has written the writer that, as no more examples of *Protocimex siluricus* have been observed, he is now of the opinion that it is not impossible that he and the entomologist may have been misled by a "lusus naturæ." Brongniart, although still retaining faith in the Silurian fossil *Paleoblattina Douvilli*, admits that it has been regarded by some as a piece of a trilobite. According to White, Kidston, and Ami, the "fern ledges" at St. John, New Brunswick, heretofore regarded as Devonian and from which several insects have been obtained, contain a Carboniferous flora closely related to that of the lower part of the Upper Carboniferous, or the Meso-Carboniferous. Papers by Dr. G. F. Matthew may be consulted, however, in which the deposits are referred to a much earlier terrain.

The classification of Paleozoic insects and their relation to Mesozoic and recent forms are still in an unsettled condition. The Permian types coming in the interval between the better known forms of the Coal Measures on the one hand and of the Mesozoic on the other will perhaps throw some additional light on the interrelation of the older and younger members of the class.

Paleontological Laboratory, Yale University Museum,
New Haven, Conn., June 24, 1903.

ART. XXXII.—*Note on the Constants of Coronas;* by C. BARUS.

1. IN the course of my work with atmospheric nucleation, it appeared that the standardization of coronas which I published some time ago* is inadequate for the purpose. A revision has become necessary of such a kind as to include the features which have developed in the intervening time, in particular the occurrence of marked periodicity in the nucleation (n particles per cubic centim.) as related to aperture, and of the exhaustion losses of which there was no indication in my earlier work. The origin of the latter was for a long time puzzling, but they are now completely referable to the subsidence of fog during the brief period within which the coronas are visible and the nuclei loaded by condensation. I will show elsewhere that if successive identical partial exhaustions of the volume ratio y are presupposed, the phenomena are expressed by

$$n_z = n_Z \, 10^{(z-Z)\log y} \prod_{Z}^{z-1} (1 - S/s^2)$$

where Z is the number of the fiducial and z of any subsequent exhaustion, n_Z and n_z the corresponding nucleations, S the appropriate subsidence constant and s the current relative aperture of the corona. Π is the function $(1-S/s_Z^2)(1-S/s_{Z+1}^2)$ $\ldots\ldots(1-S/s_{z-1}^2)$. The constant S may either be computed from observation of s and n in the region of normal coronas (where $n = C s^3$ is known) or it may be computed from the observed time of fog suspension. Clearly all observations must be made strictly in time series.

To be independent of the optics of coronas which are not worked out, I have determined the diameter of fog particles from subsidence experiments. Thus for an observed aperture, s_o, the diameter d_o, from subsidence gives the fundamental constant, $s_o d_o = a''$. This constant differs materially from $a' = d\,s$ as found from diffraction measurements, as the tables show. The corresponding n values in the former case are about twice as large as the n values in the latter, seeing that the cube of a enters the equations.

2. *Explanation of tables.*—To correlate the present with my earlier investigations I will give a series of results found by using a small circular part of the Welsbach mantel as a source of light. Coronas in this case are more easily identified because of the simplified color scheme, to the practical advantages of which I have already referred. These are followed by results with electric light seen through ruby glass.

* This Journal, xiii, p. 81, 1902; Phil. Mag. (6), iv, 1902, p. 24.

Table 1. Constants of coronas. Condensation chamber 20^{cm} broad, 25^{cm} high, 35^{cm} long. Distances of eye and source from chamber 85^{cm} and 250^{cm}, resp. $\theta=22°$; barom. 75·3^{cm}; $\delta p=16·9^{cm}$; $y=·77$; $a=·064$; $\beta=0$; $S=2·6$; $a''=·0029$ (subsidence); $a'=·0032$ (diffraction); $n_0=209{,}000$; $m=4·7\times10^{-6}$; s measured to outer edge of first ring. Phosphorus nuclei. First Series, Welsbach lamp.

z	t	s	corona*	$n'=275\,s^3$	$n''=470\,s^3$	$N\Pi\left(1-\frac{S}{s^2}\right)$	n_0	n	$d=·021n^{-\frac{1}{3}}$
1	17m	cm	....	$\times10^{-3}$	$\times10^{-3}$	2·2	$\times10^{-3}$	460000	cm
2	20	..	b′r′	....	....	1·7	....	350000	·000290
3	23	..	g′	....	....	1·3	....	270000	320
4	27	10·3	y o b	300	403	1·000	....	210000	350
5	30	8·3	w c g	157	212	·751	....	158000	385
6	34	6·8	w p b g	86·3	116	·557	....	117000	425
7	37	6·0	g b p	59·4	80·0	·403	....	84600	475
8	41	5·8	w r g	53·6	72·2	·289	....	60700	530
9	44	4·6	w b r b p	26·7	36·0	·204	....	42800	595
10	48	4·2	w r g	20·4	27·4	·137	200	28800	680
11	51	3·7	corona	13·9	18·8	·090	208	19000	780
12	54	3·2	"	9·0	12·1	·055	221	11500	920
13	57	2·6	"	4·8	6·5	·032	205	6700	·001110
14	60	2·0	"	2·2	3·0	·015	199	3100	1430
15	63	1·3	"	·6	·8	·004	220	800	2250

Second Series. Electric and ruby light. $\theta=15·5°$; barom., 75·8^{cm}; $\delta p=16·9^{cm}$; $a=·0632$; $S=2·5$; $m=4·2\times10^{-6}$; $n_0=188{,}000$. Other data as above.

z	t	s	corona	$n'=250\,s^3$	$n''=335\,s^3$	$N\Pi\left(1-\frac{S}{s^2}\right)$	n_0	n	$d=·020\,n^{-\frac{1}{3}}$
0	min	cm		$\times10^{-3}$	$\times10^{-3}$		$\times10^{-3}$		cm
1	41	..	....	....	....	2·2	....	412000	.000269
2	44	..	v′g′r′	.. .	....	1·7	....	318000	293
3	48	..	w y g′ v′	....	....	1·3	....	244000	320
4	51	9·0	w o p g	182	244	1·000	....	188000	349
5	55	8·3	w′c y g	145	195	·746	....	140000	385
6	58	6·5	w g b p	70·2	94·1	·554	....	104000	426
7	62	5·7	w y g b	47·5	63·6	·402	....	75600	473
8	65	5·4	w r g	39·2	52·6	·286	....	53800	531
9	68	4·7	w g b p	26·0	34·8	·201	....	37800	595
10	71	4·2	w r b g	19·2	25·7	·137	188	25800	676
11	74	3·7	w y b g	12·7	17·0	·091	186	17200	775
12	78	3·1	w o b g	7·8	10·5	·056	186	10500	913
13	81	2·7	corona	4·9	6·6	·033	200	6200	.001090
14	84	2·1	"	1·9	3·1	·017	188	3100	1370
15	87	1·4	"	·7	1·0	·006	180	1000	1960

* Dashes denote approaches to a color, thus g′ is greenish. Dots denote deep color.

In table 1, z denotes the number of the partial exhaustions each of volume ratio, y, and made in succession, t the current time in minutes (the interval being about 3 min. to allow for adjustments and for diffusion), s the chord of the angular aperture, ϕ, at radius R, so that $s = 60 \sin \phi$. The eye and source of light were at distances 85 and 250^{cm} from the intervening condensation chamber and the former was focussed for long distances. The pressure and temperature of the atmosphere were P and θ, and the fixed pressure decrement on exhaustion uniformly $\delta p = 17^{cm}$, nearly, so that the precipitate per cub. cm. is $m = 4{\cdot}7 \times 10^{-6} g$. Measurements were made to the outer edge of the first ring. In the column marked "coronas," the color of the annuli is specified from within outward, using obvious abbreviations. The nucleation is marked n' if computed from the aperture s, standardized with lycopodium, n'' if computed from s standardized by subsidence measurements, N if computed relatively as a geometric progression, n when the latter is reduced as suggested and the absolute values corrected for time and exhaustion losses, etc. The arbitrary initial nucleation is shown under n_0, and corresponds to $z = 4$. The other coefficients are β, referring to time losses, a referring to exhaustion losses, S referring to subsidence losses. Though n is measured for the partially exhausted receiver, a final correction $(1/y)$ need not be added, for the influx of filtered air leaves the nucleation undisturbed. The ratio $n'/N = 275\ s^3/10^{z \log y}$ if constructed in charts, shows the wide departure from the constancy which would be anticipated. Diameters of the fog particles are given under d, the equation referring to the method of computation. All data will be fully discussed later.

As to the nature of the color sequences of the first ring of coronas corresponding to successively increasing sizes of particles, the clue may be obtained from extremely small particles and excessively large (opalescent) coronas, using the electric light as a source. In such a case the colors follow the order of wave-length, and one sees w v, w b, w g, w y, w o, w r, w c, with all intermediate color gradations. In succeeding series this is repeated with more and more overlapping until after two cycles have been passed all periodicity is lost (appreciably) in the normal coronas.

If the data of the table be mapped out graphically in terms of s, the periods of n and d are now sharply marked. In the d curves for instance, cusps in the region of 6, 4, 3, 2 times ·00018^{cm} (large in comparison with wave-length) may be recognized.

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ART. XXXIII.—*Note on a Radio-active Gas in Surface Water;* by H. A. BUMSTEAD and L. P. WHEELER.

DURING the visit of Prof. J. J. Thomson to New Haven last spring, he called the attention of the writers to the work done in the Cavendish Laboratory on a radio-active gas found in waters coming from deep levels. At his request we undertook to ascertain if a similar gas existed in the deep level waters of this locality. For this purpose water from a spring near New Milford, Conn. of an estimated depth of 1500 feet was obtained, the gas driven off by boiling and tested in an electroscope. The normal air leak was found to be increased about three times. The gas was very much diluted owing to air spaces in the boiling apparatus, so that the leak found does not represent the real activity of the gas as it comes from the water. In the meanwhile the water from one of the New Haven city reservoirs (an artificial lake fed entirely by surface drainage) was tested and found, somewhat to our surprise, to contain a strongly active gas. From 7·5 liters of this water about 175^{cc} of gas were obtained and this introduced into a Wilson electroscope of about 380^{cc} capacity increased the normal air leak about twelve times. The result was the same whether the water came through the city supply pipes or was obtained directly from the lake. Water, from which the gas had been expelled and which was aerated by dropping, had not recovered the power of giving off a radio-active gas after sixteen days. This would indicate that the gas is not an emanation from any radio-active substance dissolved in the water; and this is further evidenced by the fact that the residue from the water is very slightly, if at all, active.

In casting about for an explanation of the presence of an active gas in surface water, where none had been found in England, we were led to test the gas drawn from the ground (about five feet deep), which proved to be approximately three times as radio-active as the gas from the surface water. The rate of decay of the activity of both gases was measured by enclosing a sample of each in a gas-tight electroscope and taking readings twice daily for two weeks. The curves obtained are identical within the limits of accuracy of the measurements, and show an initial rise of activity lasting four or five hours and a subsequent falling off which follows fairly well an exponential curve. The activity falls to half its value in a time very close to four days. After the gas is blown out the excited radio-activity on the walls of the electroscope can be detected for about two hours. In these respects these gases follow closely the behavior of the emanation from radium as determined by Rutherford and Curie. Further investigation of the properties of the gases is in progress.

Sheffield Scientific School of Yale University,
New Haven, Conn., Sept. 16, 1903.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Radium and Helium.*—Speaking at a dinner of the Society of Chemical Industry at Bradford, England, last July, Sir William Ramsay announced that he and Mr. Soddy, of Montreal, who has been working in his laboratory, had found that helium is a constituent of the gas emanating from radium. The gas from radium was first passed through a tube cooled with liquid air, in which the active part of the emanation was condensed and remained behind, while the gas which passed through, when examined in a microscopic Plücker tube, showed undoubtedly the whole spectrum of helium. There is, in Ramsay's opinion, a production of helium continuously from radium.

A few days after the above announcement was made, a statement appeared in the London *Times* that Sir W. and Lady Huggins, upon photographing the spectrum of the light emitted by radium at ordinary temperature, had obtained eight definite bright lines in the ultra violet, entirely different from the spark-spectrum of radium, four and perhaps five of which lines agreed with the lines of helium.—*Chem. News*, lxxxviii, 39. H. L. W.

2. *The Action of Salts of Radium upon Globulins.*—W. B. Hardy has given an account of some experiments carried out in the laboratory of Sir William Crookes, and with his assistance.

Two solutions of globulin from ox serum were used, one electro-positive, made by adding acetic acid, the other electro-negative, made by adding ammonia.

They were exposed in shallow cells, one wall of which was made of thin mica, to the radiations from 50 m.g. of pure radium bromide, enclosed in a capsule covered with mica, so that two sheets of mica were interposed between the radium and the solution. No action took place in one hour. The globulin was then exposed as naked drops, separated by 3 mm. of air from the radium salt, with suitable controls, shielded from the radium. In the positive solution the opalescence rapidly diminished—that is to say, solution became more complete. The negative solution was turned to a jelly, at first transparent, rapidly becoming opaque. The action was complete in about three minutes.

Radium, like other radio-active bodies, gives off matter in three states—(1) an emanation having the mobility of a heavy gas, (2) positively charged particles of little penetrating power, and relatively large size, (3) ultra-material negative particles, of a size much smaller than atoms. A mica plate will screen off 1 and 2, therefore the globulin solutions are unaffected by the ultra-material negative particles. The rate of action and conditions of the experiment make it unlikely that the emanation was the active agent, though, owing to its nature, intense solvent or coagulating power may safely be predicated of it. The action observed may

be almost certainly due to the positive particles. These are of material dimensions.

Globulin systems, therefore, seem to be completely transparent to the ultra-material electrons, and so too, probably, are the living tissues, since the physiological influences of the discharges from radium seem to be limited to a superficial layer a few millimeters deep.— *Chem. News*, lxxxviii, 73.

3. *Chlorine Smelting with Electrolysis.* — In a paper read before the Faraday Society, JAMES SWINBURNE gives an outline of a novel metallurgical process, which, if successful, promises at least to revolutionize the treatment of certain complex ores, particularly those containing zinc and lead together, which present great difficulties when treated by the present methods of smelting.

The first operation, which is the distinctive feature, consists in forcing chlorine gas, under pressure, into a receptacle, called the transformer, which resembles a blast-furnace. The chlorine is here made to act upon sulphide ores with the result that metallic chlorides are formed and sulphur distils off. The heat produced by the reaction is sufficient to effect the distillation and to fuse the chlorides. Chloride of sulphur is not formed as long as the sulphides are in excess, hence the sulphur in the ores is saved as such. The chlorides are tapped from the transformer in the molten condition. The next step usually consists in treating the chlorides with water to separate soluble chlorides from insoluble ones, and also to separate gangue which comes from the furnace suspended in the fused chlorides. The subsequent operations depend upon the nature of the chloride mixture. Lead and silver chlorides are dried and fused in contact with metallic lead, which extracts the silver and any gold; the lead chloride is then fused in contact with metallic zinc, which gives lead practically pure, and anhydrous zinc chloride. The soluble chlorides are treated with spongy copper, when lead and silver are precipitated; then copper is precipitated with "cement" zinc. Ferric oxide is then precipitated, after the solution has been oxidized by chlorine, by means of zinc oxide, and manganese dioxide is separated by the further action of the same reagents. The final liquid, containing only zinc chloride, is evaporated to dryness, and the anhydrous chloride is fused and electrolyzed with the formation of metallic zinc and chlorine. The chlorine thus produced is then used for the decomposition of ore, and is thus used over and over.— *Chem. News*, lxxxviii, 63. H. L. W.

4. *The Mazza Separator for Gases.* — For a long time centrifugal force has been used as a means of separating liquids of different densities, as in the well-known cream separators. A process for separating gases from their mixtures, depending upon the same principle, has been recently devised by SIGNOR MAZZA, formerly an officer in the Royal Engineers of the Italian Army. The machine consists essentially of a drum revolving with great velocity, into which the gaseous mixture is sucked in consequence of the rotation, and the components, divided by the effect of

centrifugal force, are automatically driven out by the same means. It is stated that it is possible in this way to obtain air so much enriched in oxygen as to make it much more effective in the combustion of fuel, and it is expected that the applications of the process will be important in metallurgical operations, in the production of steam, etc. It is expected, also, that the method will be used in the treatment of illuminating gas in order to separate a mixture rich in hydrogen from one of higher heating and illuminating power, and also for separating a large part of the carbon dioxide from blast-furnace gases, in order to make them more efficient.—*Chem. News*, lxxxviii, 68, 76. H. L. W.

5. *A Double Salt of Potassium and Barium Nitrates.* — A double salt having the formula $K_2Ba(NO_3)_4$ has been prepared by Wm. K. Wallbridge of the Sheffield Laboratory. The compound is remarkable because double salts of alkali metals and barium have been entirely unknown, and also because double nitrates are very rare. For these two reasons the salt is a very unusual one, and one whose existence would not be expected from analogy. The salt crystallizes from solutions containing the components under considerably varying conditions, but the crystals are very rough and opaque. They are tetrahedral in habit, like simple barium nitrate, and the author suggests that it is possible that their structure is pseudomorphic.—*Amer. Chem. Jour.*, xxx, 154. H. L. W.

6. *Light Waves and their Uses;* by A. A. Michelson. 166 pp. Decennial Publications of the University of Chicago, 1903. —The eight lectures which make up the present volume were delivered at the Lowell Institute in 1899, and it is a source of satisfaction to all who are interested in physics that their publication has not been longer delayed. Among instruments of precision there are few which rival Professor Michelson's interferometer in simplicity, in accuracy and in wide range of application, and perhaps none which is so interesting in respect to the natural phenomena which it incidentally illustrates. The author has succeeded in giving an admirably clear and simple account of the phenomena of interference, and of the many important researches which he has carried out by means of the interferometer and the echelon spectroscope. The presentation is so skilfully managed that the book can scarcely fail to hold the interest of the general reader, while at the same time physicists and astronomers will find in it much valuable information. H. A. B.

7. *The Sub-Mechanics of the Universe;* by O. Reynolds. xvii + 254 pp. Published for the Royal Society of London. Cambridge, 1903.—In this memoir Professor Reynolds believes that he has shown that there is "one, and only one, conceivable purely mechanical system capable of accounting for all the physical evidence, as we know it, in the Universe." Whether this belief is correct in whole or in part, whether the author's fundamental hypotheses are reconcilable with all known facts, and, more particularly, whether, if this be a legitimate explanation, it

is the only conceivable one, are questions which only time and careful criticism can settle. But in any event the work is a very remarkable one and will doubtless receive the careful attention of mathematical physicists both on account of the distinguished reputation of the author and of the extraordinary results which he has obtained. The theory assumes, as the substructure of the universe, a system of uniform spherical grains of changeless shape and size, so close that they cannot change their neighbors but are continually in relative motion with each other. Where the grains are in normal piling the properties of the medium can (by properly choosing the diameter, mean relative velocity, and mean path of the grains) be made identical with those of the ether within the limits of observational accuracy. If, in any space, the number of grains is less than in normal piling, such "negative inequalities" will move without resistance through the medium, will possess an apparent mass and will attract each other with a force varying inversely as the square of the distance; these are therefore taken to represent the molecules of ordinary matter. In a similar manner, electrical changes are accounted for by a different sort of inequality in the piling of the grains, and the mechanical structure of the granular medium is shown to be capable of accounting for many of the phenomena of electricity and of light. Like Professor Reynolds' other works, the memoir is throughout marked by great originality of thought and analytical skill. H. A. B.

II. Geology and Mineralogy.

1. *U. S. Geological Survey;* C. D. Walcott, Director.—The following publications have recently been issued:

Twenty-third Annual Report, 1901–02, 206 pp., 26 pls. 436 persons are now on the roster of the Geological Survey and the appropriation for 1901–02 was $1,079,800. In addition to the regular geologic and topographic work, the survey has now in charge the reclamation of the arid lands. The ideas advanced in 1877 by Major Powell, then Director of the Survey, regarding the arid regions have at last been enacted into law. In the matter of publications, great improvement is shown. Hereafter the annual report will be confined to one volume and the matter formerly contained in the unwieldy reports is to be published as "professional papers." The work in Alaska is in charge of four parties and is yielding results of great scientific and economic value. (See Professional Papers, Nos. 1, 2, 10.)

Professional Papers. No. 1. Preliminary Report on the Ketchikan Mining District, Alaska; by A. H. Brooks, 120 pp., 2 pls., 6 figs.

No. 2. Reconnaissance of the Northwestern Portion of Seward Peninsula, Alaska; by A. J. Collier, 68 pp., 12 pls.

No. 4. The Forests of Oregon; by Henry Gannett, 33 pp., 7 pls.

No. 5. The Forests of Washington—A Revision of Estimates; by HENRY GANNETT, 36 pp., 1 map.

No. 6. Forest Conditions in the Cascade Range, Washington; by FRED G. PLUMMER, 39 pp., 11 pls.

No. 7. Forest Conditions in the Olympic Reserve, Washington; by A. DODWELL and T. F. RIXON, 107 pp., 20 pls.

No. 8. Forest Conditions in the Northern Sierra Nevada, California; by J. B. LEIBERG, 186 pp., 12 pls.

No. 9. Forest Conditions in the Cascade Range Reserve, Oregon; by H. D. LANGILLE, F. G. PLUMMER, A. DODWELL, T. F. RIXON and J. B. LEIBERG. With an Introduction by Henry Gannett, 289 pp., 41 pls.

No. 10. Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska; by WALTER C. MENDENHALL, 65 pp., 9 pls.

WATER SUPPLY AND IRRIGATION PAPERS. No. 77. The Water Resources of Molokai, Hawaii; by WALDEMAR LINDGREN, 60 pp., 4 pls. Molokai, the fifth in size of the Hawaiian Islands, is of basalt fringed by coral reefs on the south. There are no impermeable strata, and the extreme porosity of the rocks allow free access of sea water as well as of rain, and zones of varying salinity result.

No. 78. Preliminary Report on Artesian Basins in Southwestern Idaho and Southeastern Oregon; by I. C. RUSSELL, 51 pp., 2 pls., 3 figs. Four artesian basins are described by Prof. Russell and a sketch of the general geology of the Idaho-Oregon region is given.

No. 79. Normal and Polluted Waters in Northeastern United States; by M. D. LEIGHTON, 186 pp., 17 figs., 148 analyses and tables. The river systems discussed are the Merrimac, the Blackstone, the Connecticut and its tributaries, the Housatonic, the Delaware, and the Ohio.

FOLIOS. No. 87. Camp Clarke Folio, Nebraska; by N. H. DARTON.

No. 88. Scotts Bluffs Folio, Nebraska; by N. H. DARTON. Western Nebraska shows typically the geological conditions of the Central Great Plains area. It is a region of flat-lying sediments, including volcanic ash, not older than the Eocene. Erosion has developed "bad land" topography in the soft strata. As illustrations of simple structures the Camp Clarke and Scotts Bluffs folios will serve as Physiographic texts.

No. 89. Port Orford Folio, Oregon; by J. S. DILLER. Taken in connection with the Coos Bay folio (No. 73), the Port Orford folio furnishes a description of an area adjoining the Pacific coast large enough to give a clear idea of the geological structure of the region. The area is chiefly occupied by pre-Cretaceous schists of sedimentary origin and sandstones of Cretaceous and Tertiary age. The igneous rocks are gabbros (basic and acid types) with corresponding basalts, serpentines and dacite porphyry dikes. The region has undergone a series of elevations and depressions apparently without faulting.

No. 90. The Cranberry Folio, North Carolina-Tennessee; by ARTHUR KEITH. The mapping of the Cranberry district involves the solution of some of the most difficult problems in Appalachian geology. The region includes gneisses and granites of Archean age, Algonkian? schists, rhyolites and diabases, Cambrian sediments and basalt. The metamorphism has been extreme and the fault structure is complicated and presents some unique features. The text of this folio deserves especial mention as an illustration of what can be done to make difficult geological structure intelligible to the non-expert.

No. 91. Hartville Folio, Wyoming; by W. S. TANGIER SMITH. The Hartville area shows a section of practically horizontal sediments from Carboniferous to Recent. These stratified beds are underlaid unconformably by Algonkian metamorphics, which in turn are cut by small masses and dikes of granite and pegmatite. Iron and some copper are the economic products.

2. *The Correlation of Geological Faunas. A Contribution to Devonian Paleontology;* by HENRY SHALER WILLIAMS.—U. S. Geol. Surv., Bull. No. 210, 147 pp. Washington, 1903.

Shifting of Faunas as a Problem of Stratigraphic Geology; by HENRY SHALER WILLIAMS. (Bull. Geol. Soc. America, vol. 14, pp. 177–190, 16 pls. Rochester, April, 1903.)

These two papers present the mature ideas of their author on the subject of geological correlation. The studies were commenced in 1881 and have been carried on almost continuously since. The chief area investigated has been the Devonian region extending from Ohio across the southern counties of New York, and the sections include all the Middle and Upper Devonian strata from the top of the Onondaga limestone to the base of the Olean conglomerate.

The fauna of the typical Hamilton formation is called the *Tropidoleptus carinatus* fauna. The fauna of the Black Shales is the *Lingula spatulata* fauna. The third fauna, the Portage Shales, is characterized as the *Cardiola speciosa* fauna, while the Chemung is the *Spirifer disjunctus* fauna.

A great many of the frequency and range values of the species occurring in these fossil faunas were determined, and from the results it was possible to construct standard lists of the dominant species with their relative percentages. These must always be of great service in any faunal comparisons of the Devonian. The methods employed are of course applicable to the Silurian or any other formation, as well as to the Devonian, and similar comparative studies would result in standard lists for each.

Considerable discussion is given regarding the shifting and recurrence of faunas, and concrete examples are shown, together with the methods of their correlation. The statistics of all this work in its various aspects demonstrate the intrinsic value of fossils for measuring and indicating time. No such positive evidence is furnished by the sediments when considered on the side of their lithological constitution, their structural form, or their stratigraphical position. C. E. B.

3. *Pseudoceratites of the Cretaceous;* by ALPHEUS HYATT. Edited by T. W. Stanton.—Mon. U. S. Geol. Survey, vol. xliv, pp. 351, pls. xlvii, Washington, 1903.

This work was first submitted to the Director of the United States Geological Survey as early as 1897. It was greatly revised and extended by the author up to the time of his death in 1902, and contains the results of his last work.

The Pseudoceratites are considered as retrogressive Cretaceous ammonites, showing the sutures and simple outlines characteristic of the Triassic. They are distinctly accelerated in development as compared with the Jurassic species. It is shown under Placenticeras that the arrest of development takes effect only after the three principal lateral saddles and lobes are formed in the neanic stage. Up to this stage their development is more complex than in the young of the Jurassic species. This explains the imaginary anachronism of the group in its relations with the apparently more complicated allies of the Jurassic.

Two hundred and six species are described, belonging to fifty-two genera. C. E. B.

4. *Publications of the Earthquake Investigation Committee* in Foreign Languages. No. 13, 142 pp.—During the year 1900, 385 earthquakes occurred at Hitotsubashi, (Tokyo) Japan. The seismograms of these earthquakes have been analysed by Dr. F. OMARI.

5. *The Lilac-colored Spodumene from California.*—In a note, recently published in *Science* (Aug. 12, vol. xviii, p. 304), CHARLES BASKERVILLE discusses the remarkable phosphorescence shown by the transparent lilac-colored spodumene from Pala, California, described by G. F. Kunz in the last number of this Journal. He states that a crystal was excited "by the action of X-rays for five minutes sufficiently to cause it to photograph itself when subsequently placed directly upon a sensitive plate (thin white paper being interposed) and allowed to remain in an especially constructed padded black box in a dark room for a period of ten minutes." He also proposes the name *Kunzite*, after Mr. G. F. Kunz, for this variety of spodumene.

6. *Tabellen zur Bestimmung der Mineralien mittels äusserer Kennzeichen von Albin Weisbach.* Sechste auflage durchsehen und ergänzt von Dr. FRIEDRICH KOLBECK. Pp. viii, 120. Leipzig, 1903 (Arthur Felix).—This well known and long valued work has been revised and brought up to date by Dr. Kolbeck without essential change in form or arrangement. Since the publication of the previous edition, three years since, the honored author has passed away, his death occurring on February 26, 1901.

7. *Purchase of the Siemaschko Collection of Meteorites.*—It is announced that the collection of meteorites of the late Julien de Siemaschko of St. Petersburg, containing some three hundred and sixty different occurrences, has been purchased by Prof. H. A. Ward and added to the Ward-Coonley collection, preserved in Chicago. A catalogue of this collection, numbering now 580 kinds, is promised for the near future.

8. *Meteoritenkunde* von E. COHEN. Heft II, pp. vii, 302. Stuttgart, 1903 (E. Schweizerbart'sche Verlagshandlung, E. Nägele).—The second part of Cohen's important and comprehensive work on meteorites, recently issued, is devoted to the discussion of the physical features of meteorites: the structure both of irons and stones, the crust and black veins, the form and character of the surface, the number and size of the individuals of a given fall. All of these most interesting topics are treated with care and conciseness and with especial reference to the observations and views of the many writers who have contributed to our knowledge of them. The author, however, also gives the reader the benefit of the results of his own extensive studies. The latter part of the volume (pp. 192–290) is devoted to supplements to Heft I, treating of the methods of investigation and the mineral constituents of meteorites.

9. *Meteorites from New South Wales.*—An account is given by A. LIVERSIDGE in the *Proceedings of the Royal Society of New South Wales* (vol. xxxvi, 341), of several recently discovered Australian meteorites. One of these, the Boogaldi meteorite, is an iron remarkable for its pear-shaped form and well-preserved fused crust. The others are largely stony in character; they include two masses from Barratta belonging with that found in the same locality in 1860; two masses from Gilgoin found in 1889 and 1893; also the Eli Elwah or Hay meteorite first exhibited in 1888.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Ostwald's Klassiker der Exakten Wissenschaften*, Leipsig 1903 (Wilhelm Engelmann).—The following are recent additions to this valuable series:

Nr. 20. Abhandlung über das Licht; von Christian Huyghens. 115 pp. Second edition.

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Nr. 134. Experimental-Untersuchungen über Elektricität; von Michael Faraday. Series xvi–xvii, 102 pp.

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Spodumene (Var Kunzite), Pala, California.